**AWARD NUMBER:** W81XWH-13-1-0316

**TITLE:** Maintenance of health care providers' clinical proficiency: Transdisciplinary analysis, modeling and intervention


**PRINCIPAL INVESTIGATOR:** Tim Wysocki, PhD

**CONTRACTING ORGANIZATION:** The Nemours Foundation
Jacksonville, FL



**REPORT DATE:** October 2015

**TYPE OF REPORT:** Annual

**PREPARED FOR:** U.S. Army Medical Research and Materiel Command
Fort Detrick, Maryland 21702-5012

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**4. TITLE AND SUBTITLE**
Maintenance of health care providers’ clinical proficiency: Transdisciplinary analysis, modeling and intervention

**5a. CONTRACT NUMBER**
W81XWH-13-1-0316

**5b. GRANT NUMBER**

**5c. PROGRAM ELEMENT NUMBER**

**6. AUTHOR(S)**
Tim Wysocki, PhD (tim.wysocki@nemours.org)

**5d. PROJECT NUMBER**

**5e. TASK NUMBER**

**5f. WORK UNIT NUMBER**

**7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)**
The Nemours Foundation
807 Children’s Way
Jacksonville, FL 32207-8426

**8. PERFORMING ORGANIZATION REPORT NUMBER**
Annual Technical Progress Report for Year 2

**9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)**
U.S. Army Medical Research and Materiel Command
Fort Detrick, Maryland 21702-5012

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None

**11. SPONSOR/MONITOR'S REPORT NUMBER(S)**
None

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Approved for Public Release; Distribution Unlimited

**13. SUPPLEMENTARY NOTES**
None

**14. ABSTRACT**
This 3-year partnership of the Nemours Foundation and Lockheed Martin, will: 1.) Evaluate whether physicians’ frequency of exposure to targeted clinical problems is associated with decay in physicians’ cognitive clinical skills; 2.) Develop and test multivariate explanatory models of decay in physicians’ clinical decision making; and 3.) Develop/test educational, behavioral and electronic interventions to minimize effects of skill decay on health care quality. During Year 2, we have completed selection of targeted clinical problems, identified 9 clinical problems for further study, conducted formative interviews of physician subject matter experts, collected massive amounts of electronic health record data and data on worker and workplace characteristics, demonstrated skill decay pertaining to certain elements of care pathways, and continue to test and refine initial multivariate models that were developed. We have initiated an intervention trial targeting physicians' influenza immunization practices and are soon to begin trials targeting gastroesophageal reflux disease, supracondylar fracture and concussion.

**15. SUBJECT TERMS**
Health care quality and safety; skill decay; physicians; declarative knowledge; clinical decision making; decision science

| 16. SECURITY CLASSIFICATION OF: a. REPORT | b. ABSTRACT | c. THIS PAGE | 17. LIMITATION OF ABSTRACT | 18. NUMBER OF PAGES | 19a. NAME OF RESPONSIBLE PERSON |
|---|---|---|---|---|---|
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| | | | | | 19b. TELEPHONE NUMBER *(Include area code)* (301) 619-7035 |

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1. **INTRODUCTI ON:** Narrative that briefly (one paragraph) describes the subject, purpose and scope of the research.

This project will determine how frequency of exposure to targeted clinical problems contributes uniquely, and combined with other identified variables, to affect decay in physicians' cognitive clinical skills. We have targeted 9 clinical problems that fulfill specific a-priori criteria and have identified critical elements of the care process that demonstrate evidence of skill decay with increasing time since most recent exposure to that clinical problem. We continue to evaluate new data sources that may enhance the specification of explanatory models. We are refining multivariate quantitative models to determine if skill decay can be reliably predicted based on specification of these other variables, including frequency of exposure. In Year 3, we will test behavioral, psychoeducational or electronic interventions to minimize decay in physicians' cognitive clinical skills. The project is well-positioned to be completed effectively, productively and within budget.

2. **KEYWORDS:** Provide a brief list of keywords (limit to 20 words).

Health care quality and safety; skill decay; physicians; declarative knowledge; clinical decision making; decision science

3. **ACCOMPLISHMENTS:** The PI is reminded that the recipient organization is required to obtain prior written approval from the awarding agency Grants Officer whenever there are significant changes in the project or its direction.

**What were the major goals of the project?**
*List the major goals of the project as stated in the approved SOW. If the application listed milestones/target dates for important activities or phases of the project, identify these dates and show actual completion dates or the percentage of completion.*

End of Year 1: Select targeted clinical processes and associated diagnostic or treatment procedures that will serve as the subject matter for this work; Select, refine or develop valid and reliable metrics, drawn from routinely collected EHR data to quantify variability in skill maintenance and retention within and between participating physicians regarding the targeted conditions.

End of Year 2: Perform task analysis of the knowledge, skills and proficiencies needed for optimal management of the targeted clinical processes; Refine, develop and validate measurement tools that permit reliable and valid quantification of mechanisms, processes and characteristics that are expected to mediate or moderate the observed degree of clinical skill maintenance and retention; Determine the extent to which clinical skill maintenance or decay are associated with key outcomes of children's health care.

End of Year 3: Develop and test alternative quantitative models that evaluate the separate and interactive associations of variables at the level of demographic characteristics of physicians and patients, individual characteristics of physicians and EHR data as predictors of the maintenance of clinical skill proficiency; Plan and implement a randomized controlled trial of educational or other interventions derived from the above model to enhance the maintenance and retention of clinical skills in a large sample of practicing physicians; Disseminate project results in the form of periodic required progress reports to the sponsor and the submission of abstracts, conference presentations and journal articles reporting the research findings.

**What was accomplished under these goals?**
*For this reporting period describe: 1) major activities; 2) specific objectives; 3) significant results or key outcomes, including major findings, developments, or conclusions (both positive and negative); and/or 4) other achievements. Include a discussion of stated goals not met. Description shall include pertinent data and graphs in sufficient detail to explain any significant results achieved. A succinct description of the methodology used shall be provided. As the project progresses to completion, the emphasis in reporting in this section should shift from reporting activities to reporting accomplishments.*

- We have completed the specification of 9 targeted clinical problems that met specific a-priori selection criteria and have collected massive amounts of EHR data to ensure that we are examining clinical practice dimensions that may be susceptible to decay with increasing time since prior exposure to that problem.
- We have developed the Δ-t statistic to quantify clinicians' time since prior exposure to the clinical problem of interest.
- We have completed structured task analysis interviews of multiple subject matter experts and converted the findings into a collection of EHR data elements that can be extracted to index the degree to which a given clinical encounter reflected optimal or suboptimal care vis a vis those elements of care.
- We have explored substantial 2013 retrospective EHR data relative to each of the targeted clinical problems to determine which elements of optimal care are most prone to decay with increasing values of the Δ-t statistic.
- In response to questions raised in response to our presentations at In-Progress Reviews of our work in August 2014 and August, 2015, we have explored alternative methods of multivariate modeling of the relationships between skill decay and frequency of exposure and we continue to consult regularly with our project statistician about other conceptual and analytic approaches that are available to us. We continue to work on methods of discriminating skill decay from simple non-adherence to practice guidelines among physicians and have developed several methods that we believe enable us to discriminate among these processes validly.
- We have presented and published papers reporting the above work at the Military Operations Research Society, the Interservice/Industry Training, Simulation, and Education Conference, and the American Medical Informatics Association and additional papers are in preparation.
- We have initiated recruitment of physicians for an influenza immunization intervention trial and we have additional intervention trials in preparation for supracondylar fracture, concussion and gastro-esophageal reflux disease. These will be of similar study design consisting of a 2X2 randomized treatments design manipulating independent variables consisting of comparing no intervention with computerized clinical decision supports, web-based instructional modules, or their combination on quality of care metrics validated for each targeted clinical problem. We expect to complete several such intervention trials during Year 3.

**What opportunities for training and professional development has the project provided?**
*If the project was not intended to provide training and professional development opportunities or there is nothing significant to report during this reporting period, state "Nothing to Report."*

*Describe opportunities for training and professional development provided to anyone who worked on the project or anyone who was involved in the activities supported by the project.*

*"Training" activities are those in which individuals with advanced professional skills* and *experience assist others in attaining greater proficiency. Training activities may include, for example, courses or one-on-one work with a mentor. "Professional development" activities result in increased knowledge or skill in one's area of expertise* and *may include workshops, conferences, seminars, study groups, and individual study. Include participation in conferences, workshops, and seminars not listed under major activities.*

Nothing to report. This project was not designed to provide formal training experiences to anyone, but all members of the team have benefitted from the trans-disciplinary nature of the group's collaborative interactions.

**How were the results disseminated to communities of interest?**
*If there is nothing significant to report during this reporting period, state "Nothing to Report."*

*Describe how the results were disseminated to communities of interest. Include any outreach activities that were undertaken to reach members of communities who are not usually aware of these project activities, for the purpose of enhancing public understanding and increasing*

These papers have been presented:

- Werk, L, Diaz, MC, Ingraham, L, Crutchfield, J, Franciosi, J, Wysocki, T. Structured development of interventions to improve physician knowledge retention. *Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC) 2015*
- Crutchfield, J, Ingraham, L, Wysocki, T. Validation of cognitive performance measurements to map physician declarative knowledge in practice. *Presented at the Military Operations Research Society, Alexandria, VA, 2015.*
- Wysocki, T., Diaz, MC, Werk, L, Franciosi, J, Crutchfield, J. Use of an Electronic Health Record as a Research Tool: Frequency of Exposure to Targeted Medical Conditions and Health Care Providers' Clinical Proficiency. *Presented at the American Medical Informatics Association, San Francisco, 2015.* -

This paper is under editorial review:

- Wysocki, T, Diaz, MC, Werk, L, Franciosi, J, Crutchfield, J. Use of an Electronic Health Record as a Research Tool: Frequency of Exposure to Targeted Clinical Problems and Health Care Providers' Clinical Proficiency. Submitted to the *Journal of the American Medical Informatics Association*.

**What do you plan to do during the next reporting period to accomplish the goals?**

*Describe briefly what you plan to do during the next reporting period to accomplish the goals and objectives.*

We will continue to refine the multivariate models that we have been evaluating. We will apply and test those models in intervention trials for as many of the targeted clinical problems as possible during Year 3. We have one trial in progress (influenza immunization and several others almost ready for IRB submission (gastroesophageal reflux disease; supracondylar fracture; concussion).

4. **IMPACT:** Describe distinctive contributions, major accomplishments, innovations, successes, or any change in practice or behavior that has come about as a result of the project relative to:

**What was the impact on the development of the principal discipline(s) of the project?**
*If there is nothing significant to report during this reporting period, state "Nothing to Report."*

*Describe how findings, results, techniques that were developed or extended, or other products from the project made an impact or are likely to make an impact on the base of knowledge, theory, and research in the principal disciplinary field(s) of the project. Summarize using language that an intelligent lay audience can understand (Scientific American style).*

The impact of this project will be most evident on the field of medical informatics to the extent that it may offer an excellent illustration of the integration of EHR data collection capabilities with other data sources to identify circumstances in which frequency of exposure to targeted clinical problems is predictive of decay in physicians' clinical decision making skills that may affect the outcomes, safety, cost, and efficiency of delivered care. The impact of this project will be most evident on the field of medical informatics to the extent that it may offer an excellent illustration of the integration of EHR data collection capabilities with other data sources to identify circumstances in which frequency of exposure to targeted clinical problems is predictive of decay in physicians' clinical decision making skills that may affect the outcomes, safety, cost, and efficiency of delivered care.

**What was the impact on other disciplines?**
*If there is nothing significant to report during this reporting period, state "Nothing to Report."*

*Describe how the findings, results, or techniques that were developed or improved, or other products from the project made an impact or are likely to make an impact on other disciplines.*

The project could have some impact on other disciplines that study mechanisms that affect optimal skill performance among highly trained experts in any field in which real time performance is routinely measured electronically.

**What was the impact on technology transfer?**
*If there is nothing significant to report during this reporting period, state "Nothing to Report."*

*Describe ways in which the project made an impact, or is likely to make an impact, on commercial technology or public use, including:*
- *transfer of results to entities in government or industry;*
- *instances where the research has led to the initiation of a start-up company; or*
- *adoption of new practices.*

Nothing to Report

**What was the impact on society beyond science and technology?**

*If there is nothing significant to report during this reporting period, state "Nothing to Report."*

*Describe how results from the project made an impact, or are likely to make an impact, beyond the bounds of science, engineering, and the academic world on areas such as:*

- *improving public knowledge, attitudes, skills, and abilities;*
- *changing behavior, practices, decision making, policies (including regulatory policies), or social actions; or*
- *improving social, economic, civic, or environmental conditions.*

To the extent that recent increases in health care costs are unsustainable, the project could contribute to reduction of health care costs and improvement of health care efficiency if it leads to validated methods to assess and then improve decay in physicians' optimal clinical decision making. This could lead to reductions in health care waste such as unnecessary laboratory tests, subspecialty consultations, procedures, etc., while also potentially reducing costly medical errors.

5. **CHANGES/PROBLEMS:** The Project Director/Principal Investigator (PD/PI) is reminded that the recipient organization is required to obtain prior written approval from the awarding agency Grants Officer whenever there are significant changes in the project or its direction. If not previously reported in writing, provide the following additional information or state, "Nothing to Report," if applicable:

**Changes in approach and reasons for change**

*Describe any changes in approach during the reporting period and reasons for these changes. Remember that significant changes in objectives and scope require prior approval of the agency.*

See below.

**Actual or anticipated problems or delays and actions or plans to resolve them**

*Describe problems or delays encountered during the reporting period and actions or plans to resolve them.*

The project is considerably under-spent for a wide variety of reasons that have been explained in previous quarterly and annual progress reports. We have discussed with Mr. Tony Story our proposal to utilize the unspent funds in two broad ways that constitute contract modifications. These include transferring a portion of the unspent balance of our award to Lockheed-Martin subcontract in view of their larger than expected role in the project and our intent to utilize their simulation training capabilities in intervention trials for idiopathic scoliosis and supracondylar fracture in Year 3. Second, we wish to propose an extension of the ending date of our contract from September 14, 2016 to March 14, 2017. We are submitting separate written requests for each of these proposals as instructed by Mr. Story.

**Changes that had a significant impact on expenditures**

*Describe changes during the reporting period that may have had a significant impact on expenditures, for example, delays in hiring staff or favorable developments that enable meeting objectives at less cost than anticipated.*

These changes have impacted expenditures:

1. We have been able to achieve the stated objectives of the contract to this point with less personnel time and effort than was projected.
2. We have intentionally held back on project expenditures anticipating that Year 3, with work consisting almost exclusively of intervention trials, would be by far the most expensive of the three project years.
3. Dr. David Milov, who was to occupy a key 20% FTE role in the project, experienced a catastrophic illness more than 18 months ago and he has yet to return to work. Nemours has not replaced him as Director of Medical Informatics because his eventual return has been ambiguous.

**Significant changes in use or care of human subjects, vertebrate animals, biohazards, and/or select agents**

*Describe significant deviations, unexpected outcomes, or changes in approved protocols for the use or care of human subjects, vertebrate animals, biohazards, and/or select agents during the reporting period. If required, were these changes approved by the applicable institution committee (or equivalent) and reported to the agency? Also specify the applicable Institutional Review Board/Institutional Animal Care and Use Committee approval dates.*

**Significant changes in use or care of human subjects**

Nothing to Report

**Significant changes in use or care of vertebrate animals.**

Nothing to Report

**Significant changes in use of biohazards and/or select agents**

Nothing to Report

6. **PRODUCTS:** List any products resulting from the project during the reporting period. If there is nothing to report under a particular item, state "Nothing to Report."

- **Publications, conference papers, and presentations**
  Report only the major publication(s) resulting from the work under this award.

  **Journal publications.** *List peer-reviewed articles or papers appearing in scientific, technical, or professional journals. Identify for each publication: Author(s); title; journal; volume: year; page numbers; status of publication (published; accepted, awaiting publication; submitted, under review; other); acknowledgement of federal support (yes/no).*

These papers have been presented:

- Werk, L, Diaz, MC, Ingraham, L, Crutchfield, J, Franciosi, J, Wysocki, T. Structured development of interventions to improve physician knowledge retention. *Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC) 2015*
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**Books or other non-periodical, one-time publications.** *Report any book, monograph, dissertation, abstract, or the like published as or in a separate publication, rather than a periodical or series. Include any significant publication in the proceedings of a one-time conference or in the report of a one-time study, commission, or the like. Identify for each one-time publication: Author(s); title; editor; title of collection, if applicable; bibliographic information; year; type of publication (e.g., book, thesis or dissertation); status of publication (published; accepted, awaiting publication; submitted, under review; other); acknowledgement of federal support (yes/no).*

Nothing to Report

**Other publications, conference papers, and presentations**. *Identify any other publications, conference papers and/or presentations not reported above. Specify the status of the publication as noted above. List presentations made during the last year (international, national, local societies, military meetings, etc.). Use an asterisk (*) if presentation produced a manuscript.*

- Werk, L, Diaz, MC, Ingraham, L, Crutchfield, J, Franciosi, J, Wysocki, T. Structured development of interventions to improve physician knowledge retention. *Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC) 2015**
- Wysocki, T., Diaz, MC, Werk, L, Franciosi, J, Crutchfield, J. Use of an Electronic Health Record as a Research Tool: Frequency of Exposure to Targeted Medical Conditions and Health Care Providers' Clinical Proficiency. *Presented at the American Medical Informatics Association, San Francisco, 2015.**

*Full journal articles resulted from both of the above presentations.

- **Website(s) or other Internet site(s)**
  *List the URL for any Internet site(s) that disseminates the results of the research activities. A short description of each site should be provided. It is not necessary to include the publications already specified above in this section.*

Nothing to Report

- **Technologies or techniques**
  *Identify technologies or techniques that resulted from the research activities. In addition to a description of the technologies or techniques, describe how they will be shared.*

Nothing to Report

- **Inventions, patent applications, and/or licenses**
  *Identify inventions, patent applications with date, and/or licenses that have resulted from the research. State whether an application is provisional or non-provisional and indicate the application number. Submission of this information as part of an interim research performance progress report is not a substitute for any other invention reporting required under the terms and conditions of an award.*

Nothing to Report

- **Other Products**
  *Identify any other reportable outcomes that were developed under this project. Reportable outcomes are defined as a research result that is or relates to a product, scientific advance, or research tool that makes a meaningful contribution toward the*

*understanding, prevention, diagnosis, prognosis, treatment, and/or rehabilitation of a disease, injury or condition, or to improve the quality of life. Examples include:*

- *data or databases;*
- *biospecimen collections;*
- *audio or video products;*
- *software;*
- *models;*
- *educational aids or curricula;*
- *instruments or equipment;*
- *research material (e.g., Germplasm; cell lines, DNA probes, animal models);*
- *clinical interventions;*
- *new business creation; and*
- *other.*

- Development and validation of the Δ-t statistic to measure duration of time elapsing since the prior clinical exposure to a specific targeted clinical problem and understanding of its distributional characteristics.
- Development of quality of care metrics for the 9 targeted clinical problems based on structured interviews of subject matter experts, review of published guidelines for evidence-based clinical practice, and evaluation of feasibility of HER data extraction for each such metric.
- Development of a framework for systematic development of behavioral, education and clinical decision support interventions matched to learner needs based on observations of decay in quality of care metrics as a function of increasing values of the Δ-t statistic.

## 7. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

**What individuals have worked on the project?**

*Provide the following information for: (1) PDs/PIs; and (2) each person who has worked at least one person month per year on the project during the reporting period, regardless of the source of compensation (a person month equals approximately 160 hours of effort). If information is unchanged from a previous submission, provide the name only and indicate "no change."*

*<u>Example:</u>*

*Name:* *Mary Smith*
*Project Role:* *Graduate Student*
*Researcher Identifier (e.g. ORCID ID): 1234567*
*Nearest person month worked:* *5*

*Contribution to Project:* *Ms. Smith has performed work in the area of combined error-control and constrained coding.*
*Funding Support:* *The Ford Foundation (Complete only if the funding support is provided from other than this award).*

| Personnel Name | Project Role | Researcher Identifier | Person Month Worked | Contribution to Project | Funding support from other than this award |
|---|---|---|---|---|---|
| Tim Wysocki, PhD | PI | http://orcid.org/0000-0003-4099-4639 | 3.68 | Dr. Wysocki is PI, responsible for conduct of the project and achieving the specific aims and statement of work on schedule within budget | N/A |
| M. C. Diaz, MD | Co-I | N/A | 0.98 | Dr. Diaz is a member of the Targeting Clinical Problems Working Group and the Interventions Working Group. | N/A |
| J. Franciosi, MD | Co-I | N/A | 0.59 | Dr. Franciosi is a pediatric gastroenterologist and a member of the Model Building and Analysis Working Group. | N/A |
| S. Lawless, MD, MBA | Co-I | N/A | 0.03 | Dr. Lawless is Vice President for Quality and Safety and a member of the Steering Committee. He facilitates access to data from Nemours Data Warehouse, the Physician Credentialing Database and other sources. | N/A |
| D. Milov, MD | Co-I | N/A | 0.00 | Dr. Milov is Chief of Medical Informatics and a member of the Steering Committee, Chair of the Targeting Clinical Problems Working Group and member of the Model Building and Analysis Working Group. | N/A |
| L. Werk, MD, MPH | Co-I | N/A | 2.38 | Dr. Werk is Chief of General Pediatrics at Nemours Children's Hospital in Orlando. a member of the Steering Committee and Chair of the Interventions Working Group. | N/A |
| J. Hossain, PhD | Stats. | N/A | 0.97 | Dr. Hossain is a Ph.D. Statistician and a member of the Targeting Clinical Problems and Model Building and Analysis Working Groups. | N/A |
| A.Taylor, MA | Data Mgr. | N/A | 2.71 | Mrs. Taylor has developed agenda for conference calls and meetings, drafted and posted minutes, and assisted with data extraction | N/A |
| J. Miller | EMR Spec. | NA | 1.52 | Mr. Miller coordinates extraction of data from Nemours EMR Data Warehouse | N/A |

| | | | | | |
|---|---|---|---|---|---|
| R. Villanueva | EMR Spec. | N/A | 1.98 | Mr. Villanueva evaluates and adjusts for nuances in clinical service documentation across physicians and Nemours sites. | N/A |
| E. Antico | EMR Spec | N/A | 7.43 | Mrs. Antico coordinates extraction of data from Nemours EMR Data Warehouse | N/A |
| D. Kemp | Proj. Mgr. | N/A | 1.81 | Mr. Kemp is a Certified Project Manager whose time and effort are donated in-kind by Nemours | The Nemours Foundation |
| J. Dent | Proj. Mgr. | N/A | 1.81 | Ms. Dent is a Certified Project Manager whose time and effort are donated in-kind by Nemours | The Nemours Foundation |
| J. Crutchfield, PhD | PI (LM) | N/A | 9.39 | Dr. Crutchfield is a Sociologist and expert in quantitative modeling of maintenance and decay of human performance and cognition. | N/A |
| L. Ingraham, MSCE | Sr. Project Engineer (LM) | N/A | 5.90 | Ms. Ingraham is the Project Engineer who is an expert at task analysis and matching of educational and decision support interventions to characteristics of tasks, workers and workplaces. | N/A |
| Y. Marks, PhD | Instructional Designer LM) | N/A | 2.18 | Dr. Marks is an expert at conducting interviews of subject matter experts to identify intervention targets that can lead to performance improvement. | N/A |
| T. Henfield | Instructional Designer (LM) | N/A | 0.38 | Ms. Henfield is an expert at conducting interviews of subject matter experts to identify intervention targets that can lead to performance improvement. | N/A |
| R. Marra | Instructional Designer (LM) | N/A | 0.35 | Mr. Marra is an engineer who specializes in designing interventions matched to features of tasks, workers and workplaces. | N/A |

**Has there been a change in the active other support of the PD/PI(s) or senior/key personnel since the last reporting period?**

*If there is nothing significant to report during this reporting period, state "Nothing to Report."*

*If the active support has changed for the PD/PI(s) or senior/key personnel, then describe what the change has been. Changes may occur, for example, if a previously active grant has closed and/or if a previously pending grant is now active. Annotate this information so it is clear what*

*has changed from the previous submission. Submission of other support information is not necessary for pending changes or for changes in the level of effort for active support reported previously. The awarding agency may require prior written approval if a change in active other support significantly impacts the effort on the project that is the subject of the project report.*

Nothing to Report

**What other organizations were involved as partners?**
*If there is nothing significant to report during this reporting period, state "Nothing to Report."*

*Describe partner organizations – academic institutions, other nonprofits, industrial or commercial firms, state or local governments, schools or school systems, or other organizations (foreign or domestic) – that were involved with the project. Partner organizations may have provided financial or in-kind support, supplied facilities or equipment, collaborated in the research, exchanged personnel, or otherwise contributed.*
*Provide the following information for each partnership:*
*<u>Organization Name:</u>*
*<u>Location of Organization: (if foreign location list country)</u>*
*<u>Partner's contribution to the project</u> (identify one or more)*

- *Financial support;*
- *In-kind support (e.g., partner makes software, computers, equipment, etc., available to project staff);*
- *Facilities (e.g., project staff use the partner's facilities for project activities);*
- *Collaboration (e.g., partner's staff work with project staff on the project);*
- *Personnel exchanges (e.g., project staff and/or partner's staff use each other's facilities, work at each other's site); and*
- *Other.*

The project includes a substantial Subaward with the Lockheed Martin Corporation (LMCO) Mission Systems and Training Division located in Orlando Florida. This team's expertise is a major asset to the project and consists of extensive experience in studying and remediating skill decay among military and commercial pilots as well as among health care professionals. They contribute their expertise to the study by conducting and analyzing detailed task analysis interviews of Subject Matter Experts (SMEs) in the clinical management of our targeted clinical problems; working with Mr. Miller and Mr. Villanueva to determine how critical elements of the care process for each clinical problem can be extracted from the Nemours EMR Data Warehouse, identifying critical worker and workplace variables that can be measured, and finally developing quantitative models for prediction of decay in selected clinical skills and decisions. Several documents that demonstrate fulfillment of the LMCO Statement of Work for Year 2 under this Subaward Agreement are included in the Appendix to this report.

## 8. SPECIAL REPORTING REQUIREMENTS

**COLLABORATIVE AWARDS:** For collaborative awards, independent reports are required from BOTH the Initiating PI and the Collaborating/Partnering PI. A duplicative report is acceptable; however, tasks shall be clearly marked with the responsible PI and research site. A report shall be submitted to **https://ers.amedd.army.mil** for each unique award.

**QUAD CHARTS:** If applicable, the Quad Chart (available on https://www.usamraa.army.mil) should be updated and submitted with attachments.

# Maintenance of Health Care Providers' Clinical Proficiency: Transdisciplinary Analysis, Modeling and Intervention

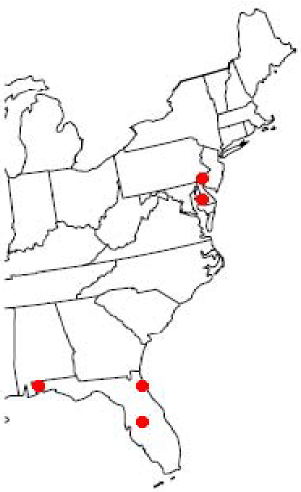
**Log Number: 12362007**
**Award Number: W81XWH-13-1-0316**

DMRDP

**PI: Tim Wysocki, Ph.D.** **Organization: The Nemours Foundation** **Award Amount: $3,936,682**

## Problem, Hypothesis and Military Relevance

- Military physicians may demonstrate skill degradation after deployment upon their return to domestic practices
- Skill degradation may impede efficiency and safety of care
- DOD delivers care to many healthy adolescent and young adult enlisted men and to military dependents, justifying research on skill degradation in pediatrics



**Nemours Locations**

**DELAWARE:** Alfred I. duPont Hospital for Children, Wilmington; Specialty Pediatrics Wilmington; Cardiac Center; Wilmington; Primary Care Pediatrics: Wilmington,,Milford, Dover,,Newark, Middletown, Seaford

**PENNSYLVANIA:** Specialty Pediatrics: Lancaster, Collegeville, Newtown Square, Philadelphia; Primary Care Pediatrics: Lankenau, Philadelphia

**NEW JERSEY:** Specialty Pediatrics: Egg Harbor Township, Vineland, Voorhees

**FLORIDA:** Nemours Children's Hospital, Orlando (opening late 2012); Specialty Pediatrics: Orlando, Jacksonville, Pensacola, Orange Park, Destin, Lake Mary, Viera

## Proposed Solution

- **Objective 1**: We will examine frequency of exposure to certain targeted medical conditions as a surrogate context for studying skill degradation among pediatric health care providers
- **Objective 2:** Develop and validate quality metrics, test alternative conceptual models and develop and test appropriate intervention strategies to prevent/minimize skill degradation

## Timeline and Total Cost

| Activities | FY13 | FY14 | FY15 | FY16 |
|---|---|---|---|---|
| Assemble research team; plan EMR and data warehouse inquires to select targeted medical conditions. Catalog and evaluate existing applicable quality metrics. | | | | |
| Develop quantitative conceptual/explanatory models of clinical skill decay among pediatric health care providers. Plan educational interventions and EMR decision support tools to prevent clinical skill decay. | | | | |
| Conduct randomized controlled trials of interventions; final statistical analysis; disseminate final project results, prepare subsequent grant applications to continue inquiry. | | | | |
| **Estimated Total Budget ($3.9M)** | $0.5M | $1.4M | $1.3M | $0.7M |

**Updated:** 12-OCT-2015

9. **APPENDICES:** Attach all appendices that contain information that supplements, clarifies or supports the text.  Examples include original copies of journal articles, reprints of manuscripts and abstracts, a curriculum vitae, patent applications, study questionnaires, and surveys, etc.

# Healthcare Skill Maintenance Model

# PERFORMANCE METRIC CONSTRUCTION

## YEAR 2 FORMAL REPORT

Prepared by:

Nemours. A Children's Health System

and

LOCKHEED MARTIN

Mission Systems & Training

Orlando, Florida 32825

March 24, 2015

For

U.S. Army, Congressionally Directed Medical Research Program

# 1. CHANGE HISTORY

| DATE | SECTION | DESCRIPTION of CHANGE |
|---|---|---|
| 03/24/2015 | - | Initial version |
| | | |
| | | |
| | | |
| | | |
| | | |

## 2. EXECUTIVE SUMMARY

Lockheed Martin, in partnership with Nemours Children's Healthcare has been contracted by the US Army's Telemedicine & Advanced Technology Research Center, (TATRC) and the Congressionally Directed Medical Research Program to investigate the phenomenon of knowledge decay and develop evidence based guidelines for determining retraining and other intervention schedules. The research committees select targeted clinical conditions for performance evaluation and analysis of knowledge decay. Measurement of performance in each targeted clinical condition will be developed using existing electronic measurement records (EMR) as a data source. This paper describes the steps used to develop a performance metric:

- Identify key knowledge
- Map knowledge to observations from EMR
- Select knowledge that decays
- Construct performance metric utility function.

# 3. TABLE OF CONTENTS

## 4. TABLE OF FIGURES

## 5. PURPOSE

This report is presented as the deliverable in response to the contractual obligations as defined in the statement:

*During the first quarter of Year 2, provision of a formal written proposal of the measurement protocol for collection of the data needed to test and compare the validity of one or more alternative quantitative models of variables associated with skill decay of pediatric health care providers.*

## 6. INTRODUCTION

Most complex knowledge is perishable. It degrades through disuse. Jobs requiring advanced technical knowledge such as pilots and physicians are not immune to knowledge decay. Job aids, retraining and refresher training programs are used to maintain minimal performance levels, but determining how much retraining is needed and on what knowledge has generally been applied through educated guesswork.

Lockheed Martin, in partnership with Nemours Children's Healthcare has been contracted by the US Army's Telemedicine & Advanced Technology Research Center, (TATRC) and the Congressionally Directed Medical Research Program to investigate the phenomenon of knowledge decay and develop evidence based guidelines for determining retraining and other intervention schedules. The research committees select targeted clinical conditions for performance evaluation and analysis of knowledge decay. Measures of performance in each targeted clinical condition were developed using existing electronic measurement records (EMR) as a data source. This paper describes the four basic steps, shown as ovals in Figure 1, used to develop each performance metric:

I. Identify key knowledge
II. Map knowledge to electronic medical records data
III. Select knowledge that evidences decay
IV. Construct performance metric utility function.

The resulting performance metric will indicate variation as a result of time between performances, and will tend to be higher for those performers whose time between performance is short. We will use it to explore other factors that may affect performance such as individual characteristics, characteristics of the workplace and characteristics of the performers themselves.

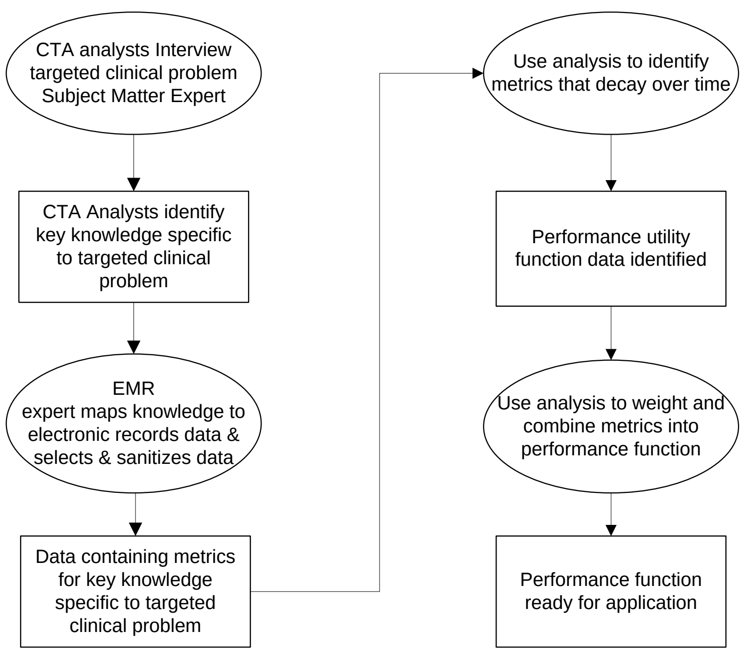



**Figure 1. Performance Metric Construction**

## 7. IDENTIFY KEY KNOWLEDGE

Each targeted clinical condition will call forth from the physician a specific set of clinical knowledge. This research is specifically interested in identifying declarative knowledge skills. The process employs a cognitive task analyst. A detailed description, shown in Figure 2, that it follows six steps:

1. Obtain and analyze available documentation on the condition
2. Construct a set of questions that will encourage the subject matter expert to express his or her knowledge of the diagnosis and treatment of the targeted clinical condition.
3. Interview the subject matter expert, using the questions.
4. Transcribe the interview.
5. Analyze the interview and additional materials and construct a draft skill set
6. Use draft skill set to extract
   - Identified comorbid conditions
   - Ordered procedures and referrals
   - Ordered pharmaceuticals
7. Review and revise the skill set with the help of the subject matter expert in a short second interview

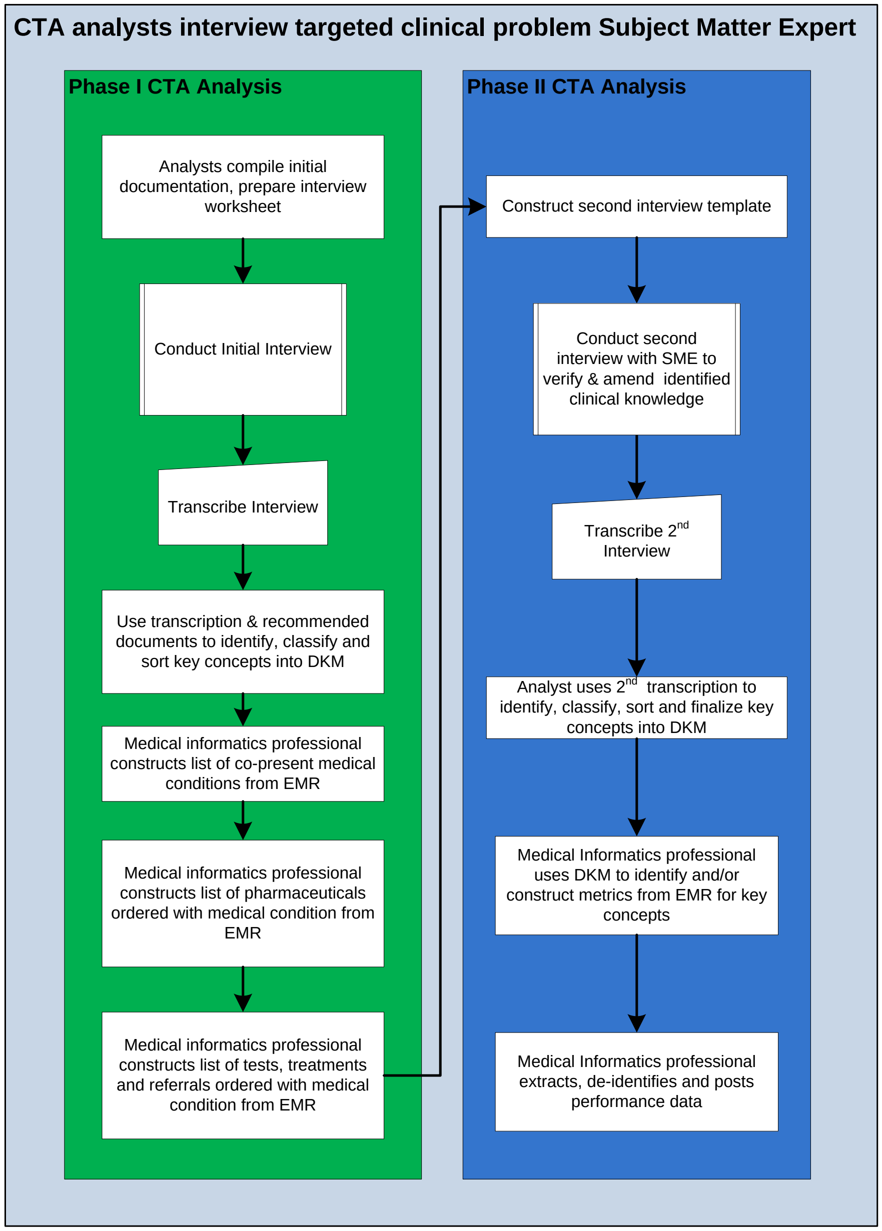



**Figure 2. Identification of knowledge and indicators of the exercise of that knowledge**

Once a set of critical skills have been identified, and reviewed by the subject matter expert, we are ready to mine the electronic medical record data for those skills.

## 8. MAP KEY KNOWLEDGE TO ELECTRONIC MEDICAL RECORD DATA

A search of the Electronic Medical Record (EMR) data dictionary is conducted to identify available metrics. Further interviews with the subject matter expert may be necessary to extract data from open-ended notation fields. This work is performed by Nemours employees since primary data sources include patient identification information.

Initially, no limitation is placed on data field selection, except that necessary to protect Health Information Protection Act (HIPA) patient identity and physician data. Unused fields or fields with no data are identified and dropped. If necessary, different tables are joined to construct a base working data set. Where necessary, identity masking techniques are employed, such as replacing identity numbers with random numbers. The resulting data set reflects actual medical histories, but with all references to the patients and their physicians masked or redacted.

Redacted data with performance metrics are extracted and stored separately for model analysis.

## 9. SELECT KNOWLEDGE INDICATORS THAT EVIDENCE PERFORMANCE DECAY

Some knowledge requirements are shared by other clinical conditions or are of such an obvious nature that under normal conditions, they do not evidence decay. There may be something about how the knowledge was acquired that may also influence retentions. Were these knowledge elements employed in the data used to construct a performance metric, they would mask the dynamic variable nature of other knowledge.

Initial attempts at constructing a performance metric for the Obesity condition was a case in point. Advising the patient and/or parents of the patient that the patient needs to lose weight and to increase exercise is a basic response. One need not be a physician to know that, though due to the particular responsibility of the physician in assisting with the health of the patient it is a more urgent matter. We found little dynamic variation in any of the performance metrics we attempted to construct. However, by removing metrics from analysis that specifically demonstrated little dynamic variation, we did find some variation. Initially we resisted this *ad hoc* response. However, once we recognized that there are classes of performance that do not vary over time, and those that do, we added an analytical step to classify those metrics prior to model inclusion.

A dynamic measure of time ($\Delta t$) was constructed that represented the time period or gap between knowledge performance events. This $\Delta t$ is the time period we hypothesize to be responsible for knowledge decay. Time is assumed to be a reasonable proxy for the unobserved processes that result in forgetting. Candidate performance metrics are plotted against $\Delta t$. Those metrics that show no trend or knowledge decay over time are deleted from the study.

## 10. CONSTRUCT PERFORMANCE UTILITY FUNCTION

At this point, for each targeted clinical condition, we have identified multiple performance metrics for knowledge that evidences decay. As shown in Figure 3, where the number of available indicators is large, greater than five, we combine them into one or more performance utility functions (PUF). Where the number of available indicators is sparse, less than five, we may use the indicators directly. Where the available indicators are few and dichotomous, we perform a logistic transformation, using the log-odds ratio of the indicator in the construction of the PUF.

*Computation of log-odds for dichotomous, yes-no variables*

Model construction with a small number of dichotomous variables requires a specific approach. The arithmetic mean value of the score at each $\boldsymbol{\Delta t}$ is computed for each healthcare giver. With dichotomous variables, this will range from zero to one. This can be interpreted as the expected value for the performance at that $\boldsymbol{\Delta t}$, "E($t$)". The odds ratio is the ratio of that value to one minus that value,

$$\frac{E(t)}{1 - E(t)}$$

The log of the odds ratio is referred to as the "log-odds ratio" also known as the "logistic transform" or "logit transform,"

$$Log_e\left(\frac{E(t)}{1-E(t)}\right).$$

This gives us a value for use as a continuous outcome variable enabling application in decay model estimation.

There are two special cases that must be addressed, when E(t) = 1 or E(t) = 0. The former condition can occur when the number of observations is low, and all indicate a positive (1) performance. In this case, the ratio computes a zero in the denominator. The second is when the performance is zero, resulting in an attempt to compute the log of zero. Both outcomes are mathematically undefined. To compensate, we add the value of 0.001 to both the numerator and the denominator,

$$Log_e\left(\frac{0.001+E(t)}{1.001-E(t)}\right).$$

This results in an approximate continuous range of about -1 to 12, which enables analysis without encountering the undefined value error.

*Computation of PUF when number of indicators greater than four*

When number of variables is greater than four, we create performance utility functions (PUF) for each of the identifiable underlying latent metrics. The variables are weighted and summed in a linear equation to produce the PUF value. We employ principal component analysis to determine these factor weights. Examination of the relative factor weights assists in identifying the latent variable driving the outcomes.

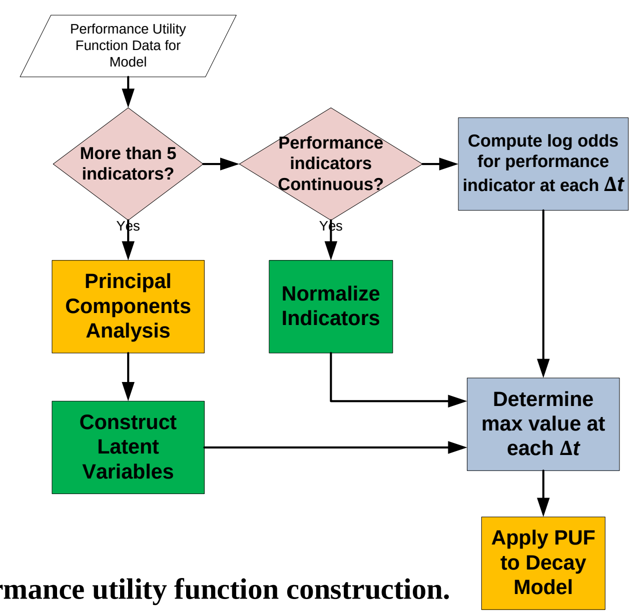



**Figure 3. Performance utility function construction.**

When the number of variables is larger, even though they may be dichotomous, they can be combined into a linear equation using this approach.

For purposes of this study, the knowledge performance metrics either directly as indicators, or indirectly as log-odds indictors are combined into one or more performance utility functions. We will use a linear function for performance, and this requires a process for determining factor weights for each of the selected metrics. We employ principal component analysis to determine these factor weights.

*Selection of max PUF to differentiate adherence in model construction*

An additional source of difficulty in determining a decay model had to do with the degree of normal variation as observed in our performance metrics. Deviation from performance guidelines, as measured through knowledge expression, may be a function of decay. However, it could also be the result of special conditions recognized and implemented at the discretion of the physician. This has been referred to as guideline adherence variation. Consequently, we observed substantial variation in performance at every time period. We also found that the maximum values of the performance functions often decreases as $\boldsymbol{\Delta t}$ increases. We can reasonably assume that this decrease in value is most likely due to knowledge decay.

## 11. EXAMPLE PUF STUDIES

The table excerpt below is from the Declarative Knowledge Matrix constructed for the study of the Obesity targeted clinical problem. It maps consolidated information from the subject matter expert interview to the individual field elements made available for analysis by the Nemours IT team.

| ID | Domain | Data Elements | Field Name(s) |
|---|---|---|---|
| Notes-> | Phase or diagnosis/ treatment step | Knowledge identified from interview and document content analysis | Name from SAS datafile |
| 1.0 | General | TCP Description | |
| 1.0.1 | | BMI 85th to 94th Percentile - Overweight | |
| 1.0.2 | | BMI > 95th Percentile - Obese | |
| | | | |
| | | | |
| 1.1 | Monitoring | Physical Description | |
| 1.1.1 | | Children should be screened by the primary care team for developmental delays (at the 9-, 18-, and either 24- or 30-mo visits) using validated instruments. | |
| 1.1.2 | | The child’s length/height and weight should be measured and documented at every well-child visit or note a reason for not doing so. | |
| 1.1.3 | | If a child is 2 y or older, the child’s BMI should be calculated and documented at every well-child visit or note a reason for not doing so. | |
| | | | |
| | | | |
| 1.2 | Monitoring | Comorbility & Complications | |
| 1.2.1 | | Anxiety | Anxiety, PL_Anxiety |
| 1.2.2 | | School Aviodance | School_Avoid, PL_School_Avoid, School_Phobia, PL_School_Phobia |
| 1.2.3 | | Social Isolation | Soc_Iso, PL_Soc_Iso, |
| 1.2.4 | | Severe Recurrent Headaches | |
| 1.2.5 | | Shortness of breath | Short_Breath + PL_Short_Breath |
| 1.2.6 | | Exercise Intolerance | Activity_Intol, PL_Activity_Intol |
| 1.2.7 | | Snoring | Snoring, PL_Snoring |
| 1.2.8 | | Apnea | Apnea, PL_Apnea |
| 1.2.9 | | Daytime sleepiness | Day_Sleepy, PL_Day_Sleepy |
| 1.2.10 | | Sleepiness or Wakefulness | Excess_Sleep, PL_Excess_Sleep |
| 1.2.11 | | Abdominal Pain | Abdom_Pain, PL_Abdom_Pain |
| 1.2.12 | | Psych Factors | Psych_Factors, PL_Psych_Factors |

Knowledge items highlighted in yellow were identified as having possible indicators in the Nemours data warehouse. The table continues below.

| ID | Domain | Data Elements | Field Name(s) |
|---|---|---|---|
| Notes-> | Phase or diagnosis/ treatment step | Knowledge identified from interview and document content analysis | Name from SAS datafile |
| | | | |
| 1.2 | Monitoring | Comorbility & Complications | |
| 1.2.13 | | Knee pain | |
| 1.2.14 | | Walking pain | |
| 1.2.15 | | Foot pain | |
| 1.2.16 | | Hip pain | |
| 1.2.17 | | Irregular Menses | |
| 1.2.18 | | Primary amenorrhea | |
| 1.2.19 | | Wheezing | |
| 1.2.20 | | Cushing's Syndrome | |
| 1.2.21 | | slipped capital femoral epiphyses | |
| 1.2.22 | | Legg-Calvé-Perthes disease | |
| 1.2.23 | | Nocturnal enuresis | |
| | | | |
| 2.0 | Trigger | Trigger | |
| 2.0.1 | | BMI 85th to 94th Percentile - Overweight | |
| 2.0.2 | | BMI > 95th Percentile - Obese | |
| | | | |
| | | | |
| 3.0 | Diagnosis | Diagnosis | |
| 3.1 | | BMI > 95th Percentile - Obese | PN_Obese, PI_Obese, Obesity_DX, PL_Obesity_DX |
| | | | |
| | | | |
| 4 | | Investigation | |
| 4.0 | Tests Ordered | | |
| 4.0.1 | | A1C | Glucose |
| 4.0.2 | | Fasting Sugar | BMP. CMP |
| 4.0.3 | | Lipid Profile | Lipid |
| 4.0.4 | | Liver Function | Liv_Funct |
| 4.0.5 | | When a primary care team ordered a blood test, x-ray, or other tests, a follow-up discussion with parents to provide those results should be documented. | |
| | | | |
| | | | |
| 4.1 | History | | |
| 4.1.1 | | Parental Obesity | Obesity_FamHX_DX, PL_Obesity_FamHX_DX |
| 4.1.2 | | Sibling obesity | Obesity_FamHX_DX, PL_Obesity_FamHX_DX |
| | | Childe Obesity History | Obesity_HX_DX, PL_Obesity_HX_DX |

| ID | Domain | Data Elements | Field Name(s) |
|---|---|---|---|
| Notes-> | Phase or diagnosis/ treatment step | Knowledge identified from interview and document content analysis | Name from SAS datafile |
| | | | |
| **4.1** | **History** | | |
| **4.1.4** | | Parental Type 2 Diabetes | |
| **4.1.5** | | Sibling type 2 diabetes | |
| **4.1.6** | | Parental Hypertension | |
| **4.1.7** | | Sibling Hypertension | |
| **4.1.8** | | Child Screen time | |
| **4.1.9** | | Child dietary habits | PI_Wt_Mngmnt, PN_Wt_Mngmnt |
| **4.1.10** | | Child Activity habits | PI_Exercise, PN_Exercise |
| **4.1.11** | | Child sleep habits | |
| **4.1.12** | | Child medications | |
| **4.1.13** | | Parental Smoking | |
| **4.1.14** | | Parental Alcohol use | |
| **4.1.15** | | Child alcohol use | |
| | | | |
| **4.2** | **Physical** | | |
| **4.2.1** | | Auscultation/Pulmonary | |
| **4.2.2** | | Auscultation/Cardio | |
| **4.2.3** | | Auscultation/GI | |
| **4.2.4** | | Shape of face | |
| **4.2.5** | | Skin color (Neck, axillar) | |
| **4.2.6** | | Hip Exam | |
| **4.2.7** | | Weight | |
| **4.2.8** | | Stature | |
| | | | |
| | | | |
| **5.0** | **Treatment** | **Treatment** | |
| **5.0.1** | | The primary care team should document in the chart about community-based services that the child and family use. | |
| **5.0.2** | | Primary care provider should explain things in an easy-to-understand way: “In the last 12 months, how often did your child’s primary care provider explain things about your child’s health in a way that was easy to understand?” | |
| **5.0.3** | | The primary care team should actively involve patient or parent(s) in decision-making: “When there was more than one choice for your child’s treatment or health care, how often did your child’s primary care team ask which choice | |
| **5.0.4** | | The primary care team should describe treatment options adequately: “In the last 12 months, when there was more than one choice for your child’s care, did your child’s primary care team give you enough information about each choice?” | |
| **5.0.5** | | The primary care team should provide guidance on other support services: “Does your child’s primary care team suggest support services and resources outside of the practice when specific needs arise (eg, diagnosis specific support groups, disability rights organizations)?” | |
| **5.0.6** | | The primary care team should work with the patient’s family to specifically develop a management plan that includes visit schedules and communication strategies. | |

| ID | Domain | Data Elements | Field Name(s) |
|---|---|---|---|
| Notes-> | Phase or diagnosis/ treatment step | Knowledge identified from interview and document content analysis | Name from SAS datafile |
| | | | |
| 5.0 | Treatment | Treatment | |
| 5.0.7 | | The primary care team should give timely referral to patients: "In the last 12 months, when your child needed a referral to a specialist, how often were you able to get the referral from your child's primary care provider?" | |
| 5.0.8 | | The primary care team should help patient/parent(s) coordinate care: "In the last 12 months, how often did you get as much help as you wanted with arranging or coordinating your child's care?" | |
| 5.0.9 | | The primary care team should follow-up with parents on visits to specialists: "How often did your child's primary care provider or staff talk with you about what happens during visits to a specialist doctor?" | |
| | | | |
| | Treatment | Referral | |
| 5.1.1 | | Referall to Behavioral Pediatrics | Ref_Behav_Peds |
| 5.1.2 | | Referall to Consultative Pediatrics | Ref_Consult_Peds |
| 5.1.3 | | Referall to Nutritionist | Ref_Nutrition |
| 5.1.4 | | Referral to Weight Management | Ref_Wit_Mngmnt |
| 5.1.5 | | Referral to Endoscopy | Ref_Endo |
| 5.1.6 | | Referral to Gastroenterology | Ref_Gastro |
| | | | |
| | | | |
| 6.0 | Monitoring | Post Treatment Monitoring | |
| 6.1 | | When the patient is 16 y of age or older, the primary care team should document a discussion with patient or parent(s) on transitioning to adult health care providers. | |
| 6.2 | | At the point of transfer, the primary care team should document the adult care provider that has been identified to eventually take over care. | |
| | | | |
| 7.0 | Prevention | Prevention & Control | |
| 7.0.1 | | The primary care team should document counseling about nutrition when a child's BMI is 85% percentile for age and gender or note a reason for not doing so. | |
| 7.0.2 | | 5 2 1 0 message, which reminds families to eat 5 fruits and vegetables, spend no more than 2 hours on screen time, include 1 hour of physical activity or active play, and consume little or no sugar-sweetened beverages | PN_521+PI_521 |
| | | | |
| | | | |
| 8.0 | General | Risks/Side Effects | |
| 8.1 | | | |
| 8.2 | | | |
| | | | |
| 9.0 | General | Resources | |
| 9.1 | | Guideline created by 14 organizations published in 12.07 | |

## 12. CONCLUSION - DISCUSSION

The determination of a performance metric is only one step of the analysis process. The resulting performance values are the measured outcome of the observed performance events. The next step will require development and evaluation of the forecast function for these performance metrics.

## 13. WORKS CITED

**There are no sources in the current document.**

**Title:** **Army Medical Nemours Project Progress Report**
**Milestone:** **Year 2 Completion Report – Modeling and Analysis Working Group**
**Date:** **14 September 2015**

| Project Information | | | |
|---|---|---|---|
| Project Identifier | Nemours Subaward for the Department of Defense (DoD) – US Army Medical Research Acquisition Act – Prime Grant Contract No. W81XWH-13-1-0316 | | |
| Project Title | Maintenance of Health Care Providers' Clinical Proficiency: Transdisciplinary Analysis, Modeling and Intervention | | |
| Project Start Date | 15-Sep-2013 | Project End Date | 14-Sep-2016 |
| Lead Organization | Nemours Children's Clinic – Jacksonville of The Nemours Foundation | | |
| Principal Investigator (PI) | Timothy Wysocki | | |
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| | | | |
| Performing Organization | Lockheed Martin Mission Systems and Training (MST) | | |
| Organization Address | 100 Global Innovation Circle Mail Point 823<br>Orlando, FL 32825 | | |
| Principal Investigator (PI) | James Crutchfield | | |
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| Report Document Information | |
|---|---|
| Author | Lorie Ingraham, Lockheed Martin PE |
| Reporting Period | From 15-Sep-2014 to 14-Sep-2015 |
| Reporting Project Phase | YEAR 2 Project Completion |
| Report Date | 14-Sep-2015 |
| Report Filename | Army Med Nemours LM YEAR 2 Project Report – Sep 2015.doc |

**Table of Contents**

## 1. Project Background Information

Frequency of exposure to specific clinical problems and processes may mediate military physicians' maintenance or decay of clinical knowledge and proficiencies. While deployed, military physicians may experience less demand for certain clinical skills. Upon resuming domestic practice, they may exhibit skill decay, reducing health care quality and safety. The study of variables that influence clinical skill decay, and of appropriate interventions, is certainly valuable. We propose a program of sequential research that leverages the unique combined resources of Nemours, one of the nation's largest pediatric health care systems, and the Lockheed Martin Corporation, with its extensive expertise in the measurement and amelioration of skill decay among pilots and other military personnel.

## 2. Summary of Achievements – Year 2: Validate a multivariate model of physicians' skill decay as a function of frequency of exposure to the targeted clinical processes

The Lockheed Martin team accomplished the following tasks during this phase:

- At least one member of the Lockheed Martin team participated in scheduled conference calls hosted my Nemours for the entire research team and Face-to-Face Workshop meetings.
- At least one member of the Lockheed Martin team participated in scheduled conference calls of assigned working groups.
- The team review, edit and discussed documents distributed for commentary. This is documented in meeting minutes located on the Lockheed Martin-hosted Project Collaboration SharePoint at: https://gtl-dom.external.lmco.com/sites/TLS_Prof_Project/Shared%20Documents/Forms/AllItems.aspx .
- Served as a resource to the remainder of the research team in terms of familiarizing the team with pertinent theoretical and empirical literature about decay in complex cognitive skills that can be applied to understanding of clinical decision making in health care.
- Consulted with the research team in evaluation of the feasibility, acceptability and psychometric validity of measurement of the predictor and criterion variables that comprise the multivariate model(s) to be tested.
- Contributed to the design and execution of process improvement activities to address any issues identified above.
- Collaborated with the project statistician to develop a comprehensive statistical analysis plan that will enable sound evaluation of each model to be tested as well as comparison of any alternative explanatory models.
- Continued data collection to obtain the data specified by any/all models to be tested, definitely including cross-sectional models and possibly including prospective models.
- Collaborated with the project statistician to implement and interpret the results of model testing and to use this analysis to guide planning of interventions to be tested in Year 3.
- Worked with the research team to document initial considerations of alternative intervention components including electronic health record decision supports; use of avatar-based or other case simulation educational experiences.
- Supported the US Army customer's **In Progress Review (IPR)** that took place in 11-Aug-2015 in Ft. Detrick, MD.

## 3. Project Meetings

The following teleconference meetings were held over the course of Year 2 in hosted by the Modeling and Analysis Working Group (Note: SharePoint link to meeting agenda is included in the table below. Minutes can be found in the same SharePoint folder):

| MEETING SUBJECT | DATE | APPROX. DURATION |
|---|---|---|
| 1. DOD-Model Building and Analysis Work Group Meeting (TELECON) 2014_0925_Agenda_DOD- | 25-Sep-2014 | 1.0 Hour |

| MEETING SUBJECT | DATE | APPROX. DURATION |
|---|---|---|
| Model_Building_and_Analysis_WG_Meeting.docx<br>Hosted by:<br>• Jim Crutchfield | | |
| 2. DOD-Model Building and Analysis Work Group Meeting (TELECON)<br>2014_1009_Agenda_DOD-Model_Building_and_Analysis_WG_Meeting.docx<br>Hosted by:<br>• Jim Crutchfield | 09-Oct-2014 | 1.0 Hour |
| 3. Nemours/LM Face-to-Face Workshop at Lockheed Martin MST Facility, Orlando FL<br>Hosted by:<br>• Lorie Ingraham<br>• Jim Crutchfield | 23-24 Oct-2014 | 1.5 Days |
| 4. DOD-Model Building and Analysis Work Group Meeting (TELECON)<br>2014_1113_Agenda_DOD-Model_Building_and_Analysis_WG_Meeting.docx<br>Hosted by:<br>• Jim Crutchfield | 11-Nov-2014 | 1.0 Hour |
| 5. DOD-Model Building and Analysis Work Group Meeting (TELECON)<br>2014_1120_Agenda_DOD-Model_Building_and_Analysis_WG_Meeting.docx<br>Hosted by:<br>• Jim Crutchfield | 20-Nov-2014 | 1.0 Hour |
| 6. DOD-Model Building and Analysis Work Group Meeting – Special Interim Meeting (TELECON)<br>2014_1211_Agenda_DOD-Model_Building_and_Analysis_WG_Meeting.docx<br>Hosted by:<br>• Jim Crutchfield | 12-Dec-2014 | 1.0 Hour |
| 7. DOD-Model Building and Analysis Work Group Meeting (TELECON)<br>2015_0108_Agenda_DOD-Model_Building_and_Analysis_WG_Meeting.docx<br>Hosted by:<br>• Jim Crutchfield | 8-Jan-2015 | 1.0 Hour |
| 8. DOD-Model Building and Analysis Work Group Meeting (TELECON)<br>2015_0122_Agenda_DOD-Model_Building_and_Analysis_WG_Meeting.docx<br>Hosted by:<br>• Jim Crutchfield | 22-Jan-2015 | 1.0 Hour |
| 9. DOD-Model Building and Analysis Work Group Meeting (TELECON)<br>2015_0212_Agenda_DOD-Model_Building_and_Analysis_WG_Meeting.docx<br>Hosted by:<br>• Jim Crutchfield | 12-Feb-2015 | 1.0 Hour |
| 10. DOD-Model Building and Analysis Work | | 1.0 Hour |

| MEETING SUBJECT | DATE | APPROX. DURATION |
|---|---|---|
| Group Meeting (TELECON)<br>2015_0226_Agenda_DOD-Model_Building_and_Analysis_WG_Meeting.docx<br>Hosted by:<br>• Jim Crutchfield | 26-Feb-2015 | |
| 11. DOD-Model Building and Analysis Work Group Meeting (TELECON)<br>2015_0312_Agenda_DOD-Model_Building_and_Analysis_WG_Meeting.docx<br>Hosted by:<br>Jim Crutchfield | 12-Mar-2015 | 1.0 Hour |
| 12. DOD-Model Building and Analysis Work Group Meeting (TELECON)<br>2015_0326_Agenda_DOD-Model_Building_and_Analysis_WG_Meeting.docx<br>Hosted by:<br>Jim Crutchfield | 26-Mar-2015 | 1.0 Hour |
| 13. DOD-Model Building and Analysis Work Group Meeting (TELECON)<br>2015_0409_Agenda_DOD-Model_Building_and_Analysis_WG_Meeting.docx<br>Hosted by:<br>Jim Crutchfield | 9-Apr-2015 | 1.0 Hour |
| 14. DOD-Model Building and Analysis Work Group Meeting (TELECON)<br>2015_0423_Agenda_DOD-Model_Building_and_Analysis_WG_Meeting.docx<br>Hosted by:<br>Jim Crutchfield | 23-Apr-2015 | 1.0 Hour |
| 15. DOD-Model Building and Analysis Work Group Meeting (TELECON)<br>2015_0528_Agenda_DOD-Model_Building_and_Analysis_WG_Meeting.docx<br>Hosted by:<br>Jim Crutchfield | 28-May-2015 | 1.0 Hour |
| 16. DOD-Model Building and Analysis Work Group Meeting (TELECON)<br>2015_0611_Agenda_DOD-Model_Building_and_Analysis_WG_Meeting.docx<br>Hosted by:<br>Jim Crutchfield | 11-Jun-2015 | 1.0 Hour |
| 17. DOD-Model Building and Analysis Work Group Meeting (TELECON)<br>2015_0618_Agenda_DOD-Model_Building_and_Analysis_WG_Meeting.docx<br>Hosted by:<br>Jim Crutchfield | 18-Jun-2015 | 1.0 Hour |
| 18. DOD-Model Building and Analysis Work Group Meeting (TELECON)<br>2015_0709_Agenda_DOD-Model_Building_and_Analysis_WG_Meeting.docx<br>Hosted by:<br>Jim Crutchfield | 9-Jul-2015 | 1.0 Hour |
| 19. DOD-Model Building and Analysis Work Group Meeting (TELECON)<br>2015_0723_Agenda_DOD-Model_Building_and_Analysis_WG_Meeting.docx<br>Hosted by: | 23-Jul-2015 | 1.0 Hour |

| MEETING SUBJECT | DATE | APPROX. DURATION |
|---|---|---|
| Jim Crutchfield | | |
| 20. DOD-Model Building and Analysis Work Group Meeting (TELECON) 2015_0813_Agenda_DOD-Model_Building_and_Analysis_WG_Meeting.docx Hosted by: Jim Crutchfield | 13-Aug-2015 | 1.0 Hour |
| 21. DOD-Model Building and Analysis Work Group Meeting (TELECON) 2015_0827_Agenda_DOD-Model_Building_and_Analysis_WG_Meeting.docx Hosted by: Jim Crutchfield | 27-Aug-2015 | 1.0 Hour |
| 22. DOD-Model Building and Analysis Work Group Meeting (TELECON) 2015_0910_Agenda_DOD-Model_Building_and_Analysis_WG_Meeting.docx Hosted by: Jim Crutchfield | 10-Sep-2015 | 1.0 Hour |

## 4. Project Deliverables

The following documents were delivered during Year 2:

1. Documented participation of at least one Lockheed Martin team member at scheduled meetings or conference calls by the entire research team or working groups as demonstrated by meeting minutes.
2. Delivered in March 2015 a formal written proposal of the measurement protocol for collection of the data needed to test and compare the validity of one or more alternative quantitative models of variables associated with skill decay of pediatric health care providers.
3. Participated in editing and conceptual/technical refinement of statistical analysis plans for evaluation of the proposed quantitative explanatory model(s) as evidenced by tracked changes and comments inserted in successive versions of such documents.
4. Developed a written data management plan that ensures the integrity of collected data and that provides procedures for data verification, quality control, recognition of outliers and out of range values and for treatment of missing data.
5. Participated in conference calls or video conferences with the project statistician during the 3rd and 4th quarters of Year 2 to achieve appropriate interpretation of the multivariate analyses of the quantitative model(s) being tested (documented in analysis write-ups).
6. Participated with other members of the research team in conceiving, drafting, editing and submitting journal articles, abstracts, posters and conference presentations reporting the results of the model building and testing activities. The Lockheed Martin team particularly contributed to the completion of two (2) accepted publications in Year 2:
   - Military Operational Research Society Symposium (2015 MORSS) Paper; Titled: "**Validation of cognitive performance measurements to map physician declarative knowledge in practice"**
   - Interservice/Industry Training, Simulation and Education Conference (I/ITSEC 2015); Title: **"Structured Development of Interventions to Improve Physician Knowledge Retention"**
7. Participated with other members of the research team in decision making about the design of the Year 3 intervention trial guided by the quantitative model testing results.

YEAR 2 End Project Report files (3) - Deliverables:

**[1] Healthcare Skill Maintenance Model Performance Metric Construction**

**(Ms Word Doc)**
Filename: "HealthcareSkillsetPerformanceMetrics_FormalReport.docx"

**[2] Research Data Management Plan (MS Word Doc)**
Filename: "ResearchDataManagementPlan.docx" including two (2) spreadsheets DataDictionary.xlsx and DKM_v8.xlsx in zip.allow file (please remove ".allow" to open)

**[3] This file: Army Med Nemours LM YEAR 2 Project Report – Sep 2015.doc**

## 5. External Dependencies

The LM team requires from Nemours the following:

- Electronic Medical Record data extractions approved for release to the research team
- Access to a SAS Analytical Computing environment
- Intervention content for prototype decision support aids and simulations.

## 6. Notes

It has been a pleasure and a privilege to be working with the Nemours Team in Year 2. We look forward to continued success in Year 3.

# Use of an Electronic Health Record as a Research Tool: Frequency of Exposure to Targeted Clinical Problems and Health Care Providers' Clinical Proficiency

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**Abstract**

The Electronic Health Record (EHR) has the potential to provide insight into possible decay in health care providers' (HCP) clinical knowledge or cognitive performance. Analyses of the contributions of variables such as frequency of exposure to targeted clinical problems could inform the development and testing of appropriate interventions to mitigate these threats to quality and safety of care.

De-identified, aggregated study data were obtained for 2013. Nine targeted clinical problems (TCP) were selected for further study. Task analysis interviews of subspecialty physicians defined optimal management of each TCP and specified quality of care metrics that could be extracted from the EHR. The *Δ-t* statistic, days since the provider's prior encounter with a given TCP, quantified frequency of exposure.

Frequency of patient encounters ranged from 1,566 to 220,774 across conditions. Mean *Δ-t* ranged from 1.72 days, to 30.79 days. Maximum *Δ-t* ranged from 285 to 497 days. The distribution of *Δ-t* for the TCPs generally fit a Gamma distribution (P < 0.001), indicating that *Δ-t* conforms to a Poisson distribution. A quality of care metric derived for each TCP declined progressively with increasing *Δ-t,* affirming that knowledge decay was detectable from EHR data.

This project demonstrates the utility of the EHR as a research tool in studies of health care delivery in association with frequency of exposure of HCPs to TCPs. Subsequent steps in our research include multivariate modeling of clinical knowledge decay and randomized trials of pertinent preventive interventions.

## INTRODUCTION

Along with the steady increase in the adoption of electronic health records (EHR) over the past decade, EHR functionality has shifted from basic systems to greater functionality featuring computerized provider order entry, result management and decision support. The government's encouragement of "Meaningful Use" of EHR systems backed by financial incentives, the growth of the Learning Health System movement, and the projected evolution of the health care marketplace from a quantity-driven to a value-driven model are among many influences that will revolutionize the current U.S. Healthcare System (1-3). As EHR becomes increasingly commonplace and institutions and health care providers become increasingly facile in using and customizing tools to document clinical encounters, there is a growing new capacity to store discrete clinical data elements that can subsequently be mined for clinical information. Specifically, the systematic use of EHR data will be used for continuous improvement and research purposes to enhance quality, safety, outcomes, cost and efficiency of care, while reducing waste, errors and duplication. In this paper, we describe our ongoing efforts to utilize routinely collected EHR data as a window into clinicians' decision making regarding the management of nine common pediatric conditions.

The pace of advances in medical knowledge continues to accelerate and health care providers are challenged with assimilating new knowledge while retaining what has already been learned. (4) Performance decay is inevitable and yet physicians cannot accurately assess their own knowledge proficiency. (5) In the health professions, quality of care (QOC) is most critical from both a human and a business perspective. The cumulative costs associated with low quality, waste, delay, and redundancy in care are great. Similar issues are encountered where high reliability is required including the military, energy and transportation sectors. (3,6)

In an era of rising healthcare costs, we are investigating a cost effective approach to QOC performance sustainment by using forecast models to provide an individualized guide to the application of interventions that will counter the effects of knowledge decay. Further, clinical declarative knowledge can be inferred by the demonstration of a caregiver's ability to recall and employ relevant knowledge for

the diagnosis and proper care of patients at the point of care, at the time that knowledge is required. Decay in relevant clinical cognitive performance is evident if EHR derived measures of clinical declarative knowledge decline over time, for instance with longer duration since the prior clinical exposure to the clinical problem of interest.

This paper describes a process that determines where the EHR archive provides sufficient data for knowledge retention forecast modeling and the selection of a limited set of key clinical issues for further investigation. In medical services and other High Reliability Organizations (HRO), QOC improvement typically yields benefits in effectiveness. (6) We believe this approach could further improve that equation by targeting for intervention specific people, circumstances or elements of the care process that may yield the greatest benefit in terms of quality, safety, outcomes and costs of care.

Therefore, the initial objective of the work reported in this paper was to find elements of the care processes for certain targeted clinical problems (TCP) that demonstrate risk for QOC performance decay that can be identified from EHR data. We sought to identify health care service issues where existing data enable a forecast model of declarative knowledge decay. In this context, we define declarative knowledge as the verbal, aural and visual information that is used by an HCP when relevant and necessary for the proper care of patients. The paper then describes the distributions of duration of time since the prior exposure to a given targeted clinical problem (the $\Delta$-*t* statistic) and affirms that there was sufficient variability in this statistic to support additional analyses. The paper concludes with analyses of associations between quality of care metrics for each TCP with increasing values of the $\Delta$-*t* statistic. Initial specification of TCPs for further study, and initial validation of the associations between clinical knowledge decay and the $\Delta$-*t* statistic are prerequisites to the subsequent phases of this research program.

The next step in this ongoing program of research consists of evaluating multivariate predictive models of decay in HCP's clinical declarative knowledge and cognitive performance, including frequency of exposure to the TCPs as a key predictor variable. That work will be followed by trials of

pertinent interventions (e.g. job performance aids, education, computerized decision supports, case simulation experiences, etc.) designed to prevent or minimize the influences of low frequency of exposure and other identified predictor variables on clinical knowledge decay.

## Method

### Setting

The activities described in this paper took place throughout Nemours Children's Health System, which owns and operates two free-standing children's hospitals (Alfred I. duPont Hospital for Children in Wilmington, Delaware and Nemours Children's Hospital in Orlando, Florida), as well as pediatric subspecialty clinics and primary care networks throughout the Delaware Valley and Florida. More than 700 doctoral level health care providers and 198 advanced practice registered nurses (APRN) are employed by the organization. All of the operating entities have utilized the same EHR (EPIC, Madison, Wisconsin) since the late 1990's and the organization supports a single EHR Data Warehouse. The system provides more than 300,000 health care encounters annually to infants, children and adolescents in these locations. The organization has received awards from the Healthcare Information Management System Society (HIMSS) for excellence in its commitment to health information technology and has consistently earned high marks for its performance relative to the HITECH Meaningful Use standards since those were implemented in 2011. The project described in this paper also involved a collaborative relationship with staff of the Mission Systems and Training division of the Lockheed-Martin Corporation, which operates a state of the art human performance engineering and simulation center in Orlando, Florida. That group brought special expertise to the project in terms of completion of detailed task analyses of optimal performance of complex skills via structured interviews of subject matter experts, identification of worker and workplace characteristics that might influence clinical skill decay/maintenance, analysis of quantitative modeling of skill decay/maintenance and matching of intervention strategies to characteristics of specific clinical skills.

### Procedure

The team's efforts to determine TCPs for further study began with examination of common diagnoses recorded in administrative data. First, the top 100 most frequently encountered outpatient diagnoses were identified. Conditions with multiple related diagnoses were aggregated. For example, asthma exacerbation with and without status asthmaticus, as well as mild, moderate, and severe asthma were classified together. Second, the Nemours Data Warehouse was then queried to extract the data necessary to further evaluate each of these clinical problems using the following criteria:

- Frequency with which the specific clinical problem was entered at a documented outpatient clinical encounter. This was analyzed to ensure that adequate multivariate analyses could be performed as rarely encountered clinical problems may not provide enough data to allow for this assessment.
- Number of Divisions across the entire Nemours Health System seeing the clinical problem and the varied types of health care providers responsible for the above visits, for example, subspecialist physicians, primary care physicians, advanced practice nurses, and physician assistants. This was queried to ensure variability in expertise and frequency of exposure.
- Variability among providers in terms of frequency of exposure to the clinical problem, again to facilitate robust and productive multivariate analyses.
- Number of unique patients presenting with the clinical problem per year and number of condition-related encounters/patient/year. This was also assessed to determine variability in frequency of exposure.
- Availability of adequate EHR data to permit quantification of frequency of exposure.
- The presence of controversy regarding optimal clinical management of the problem was not an exclusion factor and was thought to contribute to variability among providers in terms of what management steps are taken.

The research team iteratively reviewed the list of candidate clinical problems to maximize exposure to the above factors which resulted in a list of 12 candidate conditions. Third, clinical leaders from the

pertinent clinical divisions/services were enlisted to serve as Subject Matter Experts (SMEs) to assist in further selection of targeted clinical problems and to assist the team with defining optimal clinical management of the targeted clinical problem under consideration. The latter was achieved through structured task analysis interviews of SMEs, often supplemented with published evidence-based treatment guidelines, systematic reviews, and organizational policies and position statements.

From the initial list of 12 candidate conditions, the research team selected 9 targeted clinical problems for further study based on the team's capacity and the identification of physician champions for the respective TCPs.The selected TCPs included gastroesophageal reflux disease (GERD), headache, concussion, idiopathic scoliosis, encopresis/constipation, influenza vaccination, supracondylar fracture, Type 1 diabetes and obesity. The team developed a $\Delta$-*t* statistic, the number of days since the prior encounter with the index clinical problem, as its measure of frequency of exposure. In addition to the $\Delta$-*t* statistic, a number of measures of worker characteristics (provider age, race/ethnicity, years of experience, nation of origin, first language, board certifications, EHR proficiency) and workplace characteristics (# patients scheduled on date of visit, day of week of visit, time of visit, clinician's on-call responsibility) have been obtained as additional moderators and mediators.

Finally, indices reflecting provider decision making about the clinical management of the index problems were extracted from the Data Warehouse for eventual entry into quantitative models. This was achieved by first conducting separate Principal Components Analyses for each TCP, including in those analyses the various EHR data elements specified in the task analysis interviews of the SMEs. In order to ensure that the analysis was examining knowledge decay rather than HCP nonadherence with optimal care practices, the knowledge metric scores that entered these analyses consisted of the maximum score obtained at any given value of the $\Delta$-*t* statistic. (Results were similar when all scores were included in the analyses). The measurement factor that was selected for each TCP was the factor that emerged as having the highest eigenvalue for that TCP (range XX.XX to YY.YY). For each such measurement factor, EHR documentation of each encounter for each HCP with the TCP of interest was

scored in terms of the presence/absence of each of these data elements and the total score was treated as a composite quality metric for that encounter. Then, the distributions of scores on these quality metrics for each TCP was plotted as a function of the spectrum of values of the Δ-*t* statistic derived for those same encounters.

## RESULTS

The nine clinical problems we selected were evaluated across the Nemours Children's Health System, using EHR data from 2013. Table 1 illustrates the successful implementation of the criteria employed to target clinical problems for further study. Nine diverse clinical problems were selected, each of which were seen by care providers representing a large number of clinical sub-units (i.e., departments, divisions, and satellite clinic locations) (Mean = 61.8 sub-units; range 28-226 across clinical problems). A total of 1,735 different health care providers offered care to these patients (MD: 298,804 encounters; 82.3%; DO: 29,855 encounters; 8.2%; and APRN: 34,341 encounters; 9.4%). The nine targeted clinical problems were all seen commonly (Mean number of distinct patients per targeted clinical problem = 16,412.9; mean number of encounters per targeted clinical problem = 40,333.3).

Mean *Δ-t* ranged from 1.72 days for obesity, to 30.71 days for influenza vaccination. In most cases, *Δ-t* represents the time, in days, between the last encounter with a patient with the specified clinical problem. For the influenza vaccination, *Δ-t* was computed against the latest, previous administration of vaccination, since in most cases, the patient is not present solely for that issue. As would be expected, based on the lower number of cases, encopresis/constipation appeared with the next highest mean Δ-t of 21.86 days. Maximum *Δ-t* ranged from 285 days for obesity to 497 days for headaches. Obesity, encopresis/constipation and GERD demonstrated a maximum *Δ-t* of somewhat less than a year, but the rest exceeded 400 days. As seen in Figures 1, 2 and 3, the distribution of *Δ-t* fit a Gamma distribution ($P < 0.001$), indicating that, except for influenza vaccination, the intervals between successive patient encounters for these clinical problems follow a Poisson distribution. The distribution for influenza vaccination differed very slightly due to seasonality of administration, but still generally fit the distribution.

Additional exploratory analyses were performed to determine whether the derived measures of HCP's clinical knowledge varied systematically at different values of the Δ-*t* statistic. Figure 4 portrays a representative illustration of these analyses in displaying the maximum score obtained on the Concussion knowledge metric as a function of increasing values of the Δ-*t* statistic. As shown in Figure 4, the clinical knowledge score declined in a curvilinear manner with respect to longer duration since the prior exposure to Concussion as the presenting clinical problem. Table 2 (or Figure 5) summarizes the corresponding data for the other 8 TCPs, each of which also demonstrated statistically significant decline in the clinical knowledge metric with increasing values of the Δ-*t* statistic.

## DISCUSSION

EHR technology increasingly penetrates into the routine operations of health care entities, (4, 7) and these entities will increasingly compete in a value-driven health care marketplace as defined by the U.S. Department of Health and Human Services. Health care organizations that can utilize their accumulated EHR data to improve the quality and safety of care they deliver, while reducing waste, delay and redundancy will be best positioned to thrive in that environment. The work reported here describes the first step in an initiative that seeks to determine if frequency of exposure to targeted clinical problems is a risk factor for decay in HCP's clinical declarative knowledge and if timely, cost-efficient interventions can favorably impact the expression of that risk. This paper describes the first step in a planned program of research to determine if frequency of exposure to targeted clinical problems can be reliably quantified based on historic EHR data and if that measure can be shown to be associated significantly with unwanted variability in specific care practices. The research team implemented a systematic process to select targeted clinical problems using a combination of empirical criteria and careful characterization of the opinions of subject matter experts. The collection and analysis of substantial EHR data permitted derivation of an index of the duration of time in days (the *Δ-t* statistic) since a given HCP's prior exposure to a given targeted clinical problem. After consideration of numerous candidate problems, the nine targeted clinical problems that were selected for detailed

analysis included obesity, headache, idiopathic scoliosis, encopresis/constipation, gastroesophageal reflux disease, concussion, influenza vaccination, type 1 diabetes and supracondylar fractures. While reflecting diversity of pathology, assessment, management and disease course, these conditions shared certain features, including: relatively high frequency of presentation in our health care system; multiple different types of HCPs involved in the delivery of care; variability in frequency of exposure to the problem across HCPs; substantial consensus among subject matter experts regarding elements of appropriate management of each problem; variability between and within providers regarding the degree to which actual care practices conform to evidence-based care; EHR data of sufficient quality and quantity to permit the planned analyses; and adequate commitment from affected clinical divisions and services to collaborate on this project.

Distributions of the *Δ-t* statistic varied among the targeted clinical problems. These distributions approximated a Gamma distribution ($P < 0.001$) for each targeted clinical problem. However, the *Δ-t* distribution for influenza vaccination differed somewhat in shape from those for the other targeted clinical problems due to the seasonality of opportunities for such encounters.

A clinical knowledge metric specific to each TCP was derived from factor analyses of the various data elements suggested by the SMEs as indicators of optimal clinical assessment and decision making for each TCP. Exploratory analyses showed that maximum scores obtained on this knowledge metric declined significantly with increasing values of the Δ-*t* statistic for all 9 of the TCPs. These results suggest that:

- Clinical knowledge decay occurs with lower frequency of exposure to specific clinical problems and that data can be extracted from an electronic health record to identify both suboptimal levels of clinical knowledge; and
- It may be possible to identify specific HCPs who are at higher risk of subsequent decay in clinical knowledge due to longer duration of time since the prior exposure to a given clinical problem.

This could facilitate both the development and validation of a wide range of preventive and remedial interventions that could ultimately promote higher quality, safety and efficiency of care.

Use of the EHR to characterize frequency of exposure of HCPs to specific health care problems will allow health care organizations to be better prepared to identify intervention loci that can lead to improved quality and safety of care in a cost efficient manner. Targeting interventions to individual clinicians at risk for clinical knowledge or cognitive performance decay through predictive modeling would be more efficient and likely more productive than a broad training program to an entire medical staff. Identification of HCPs at elevated risk of clinical knowledge decay could prompt targeted provision of preventive education for example job performance aids such as procedural checklists, computerized decision supports at the moment of care, or simulation-based training.

Although the impact of time between successive exposures to a clinical condition has been the focus of this investigation, modeling the decay of clinical knowledge and cognitive performance will be an iterative process that will require consideration of co-factors such as clinician characteristics (e.g. age, education, and baseline knowledge), practice characteristics (e.g. specialty and workflow), and system characteristics (e.g. availability of resources). Subsequent steps in our research include building a multivariate predictive model of clinical skill decay and testing interventions focused on preventing decay of clinical knowledge.

The primary limitations of this work are the recognition that the quality of care that is actually delivered and the EHR documentation of that care may diverge and the difficulty inherent in attempting to distinguish between decay in clinical knowledge versus simple noncompliance by HCPs. We address these two points sequentially below. Also, it is important to recognize that this paper (See Figure 4) demonstrated clinical knowledge decay by analyzing aggregated cross-sectional data that revealed increasing decrements in clinical performance in association with time since the HCP's prior exposure ($\Delta$-t) to that TCP. This is different from a prospective demonstration that the magnitude of decay in clinical knowledge of individual HCPs is directly proportional to the amount time since that HCP's prior exposure to that TCP. A study of that type would require many repeated observations of the pertinent

quality of care metrics and the Δ- t statistic for successive clinical encounters for the same HCPs over time.

In certain instances, such as whether a specific medication or laboratory test is ordered, EHR documentation is very likely to be an extremely valid indicator of the actual events transpiring during a care encounter. However, an HCP's failure to document the rationale for departing from accepted care practices in a specific instance could be interpreted as suboptimal care when it was actually appropriate clinically. As EHR use becomes increasingly typical in health care, as HCPs become increasingly facile with its use, and as natural language processing technology advances the capacity to analyze narrative text contained in progress notes, the utility of the EHR as a tool for analyzing and facilitating quality, safety and efficiency of care will likely grow accordingly. (8) Organizations that are well-positioned to capitalize on the opportunities afforded by those developments will be able to compete more effectively in the coming value-driven health care economy.

Decrements in HCP's clinical performance as evidenced by lower scores on the metrics that were collected as indicators for this study could presumably reflect decay of clinical knowledge as well as HCP noncompliance with currently accepted standards of care. We attempted to circumvent this interpretive complication by focusing our analyses on the maximum score on our knowledge metric for each TCP at each value of the *Δ-t* statistic. It is implausible that compliance with accepted standard clinical practice related to each TCP should deteriorate systematically in association with increasing *Δ-t* but quite plausible that clinical knowledge would do so.

Subsequent steps in our research include building a multivariate model to enable prediction of clinical skill decay/maintenance and to test a range of interventions focused on preventing decay of clinical knowledge and skills. Data collection for the model-testing phase includes extraction of extensive 2013 EHR data relative to each targeted clinical problem as well as available data on worker characteristics (e.g., HCP demographics; training and certifications; years of clinical experience; EHR proficiency) and workplace characteristics (e.g., density of clinic schedule; temporal distribution of encounters early or late in the day; on-call previous night versus not). Model building and analysis of

the 2013 data will be followed by prospective evaluation of the model during the final phase of this project when a variety of job aids, educational, decision-support and simulation interventions will be tested for feasibility, acceptability and efficacy. Collectively, our work will be used to identify and target specific areas where quality of care (QOC) improvement efforts align with "Meaningful Use" EHR systems through a High Reliability Organization and continue to move towards a value-driven U.S. Healthcare EHR system model that can have the greatest payoff and offer cost effective solutions.

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Table 1. 2013 descriptive statistics for each of the 9 targeted clinical problems.

| Condition | Obesity | Influenza Vaccination | GERD | Encopresis Constipation | Headache | Concussion | Supracondylar Fracture | Idiopathic Scoliosis | Type 1 Diabetes Mellitus |
|---|---|---|---|---|---|---|---|---|---|
| Encounters | 89753 | 220357 | 25453 | 1633 | 9686 | 2977 | 2285 | 10025 | 5982 |
| Mean delta-t (days) | 1.72 | 30.71 | 3.66 | 21.86 | 7.11 | 13.21 | 11.58 | 6.78 | 4.81 |
| Max delta-t (days) | 285 | 470 | 336 | 349 | 497 | 470 | 475 | 409 | 437 |
| # Distinct Patients | 34737 | 87114 | 9010 | 880 | 5564 | 1378 | 1097 | 5586 | 2340 |
| # Distinct Providers | 518 | 246 | 192 | 122 | 214 | 132 | 88 | 158 | 65 |
| # Distinct Departments | 226 | 80 | 37 | 44 | 37 | 35 | 31 | 37 | 28 |
| # Distinct Specialties | 33 | 6 | 3 | 4 | 3 | 4 | 3 | 3 | 3 |
| # APRN Encounters | 3331 | 25145 | 2543 | 159 | 180 | 282 | 46 | 245 | 2410 |
| # MD Encounters | 79997 | 178942 | 20527 | 1316 | 922 | 2472 | 1978 | 9118 | 3532 |
| # DO Encounters | 6425 | 16270 | 2374 | 158 | 3442 | 223 | 261 | 662 | 40 |

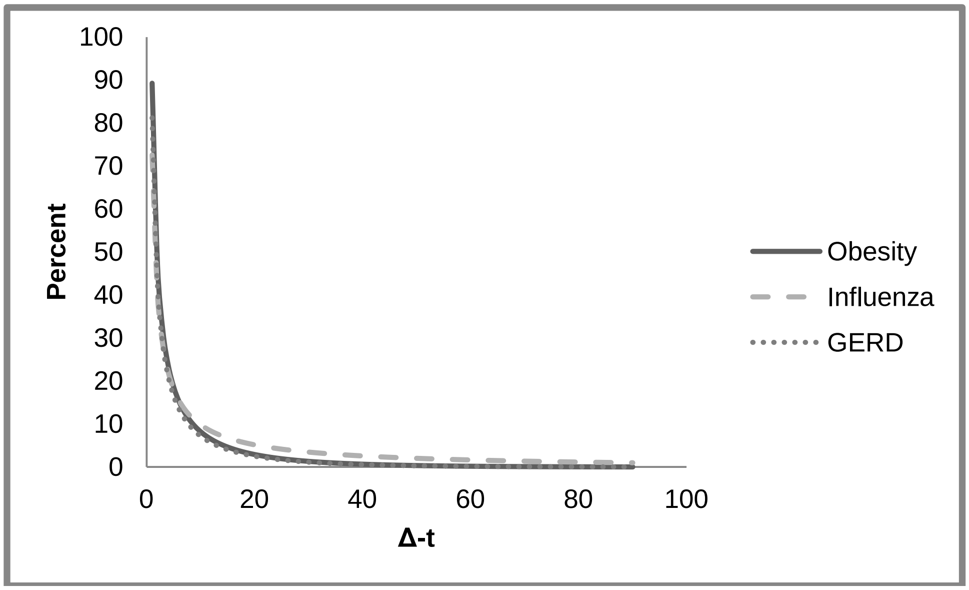


Figure 1.  Percentage of patient encounters for obesity, influenza vaccination and gastroesophageal reflux disease at obtained values of Δ-t .

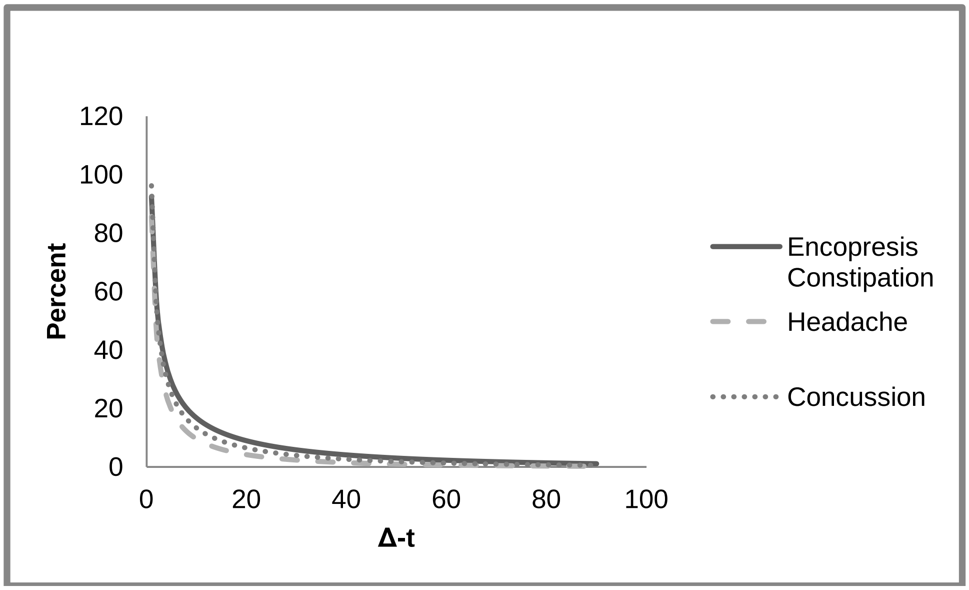


Figure 2. Percentage of patient encounters for encopresis/constipation, headache and concussion at obtained values of Δ-t.

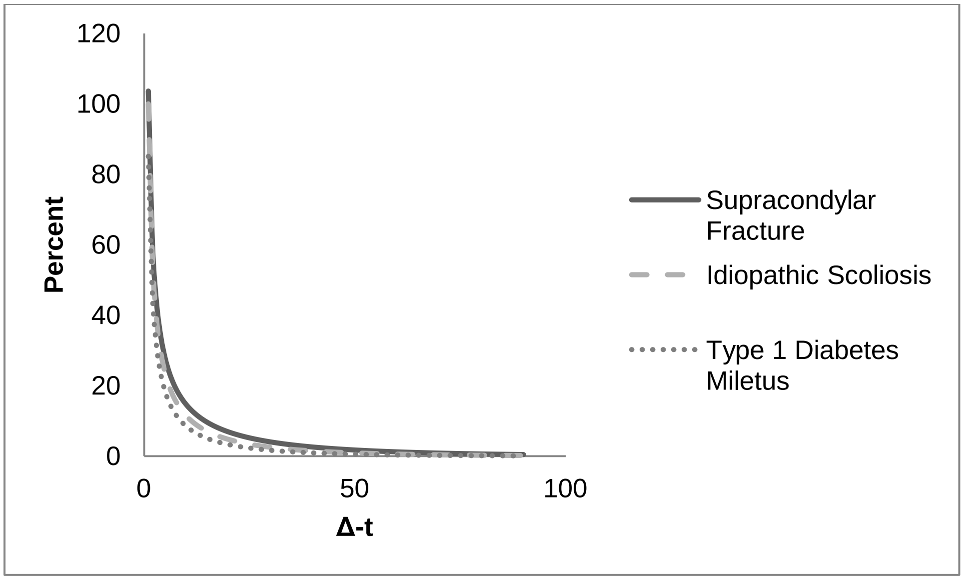


Figure 3. Percentage of patient encounters for supracondylar fractures, idiopathic scoliosis and type 1 diabetes mellitus at obtained values of Δ-t.

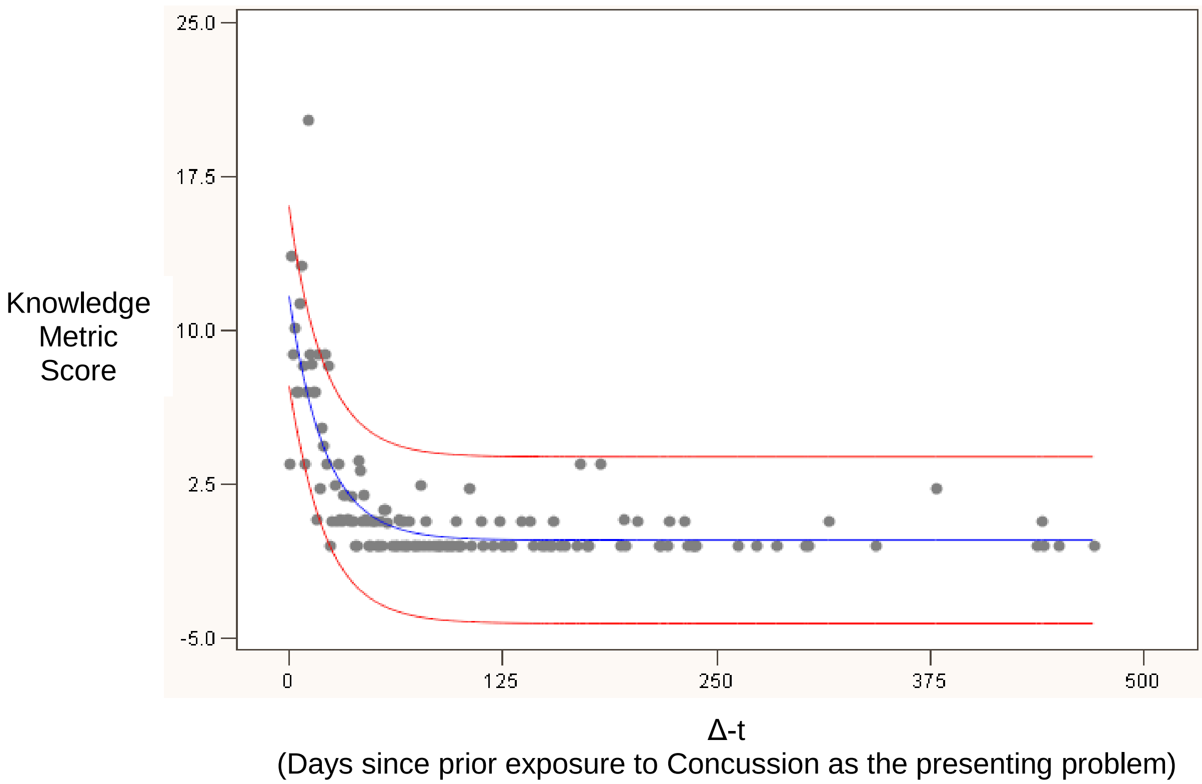


Figure 4. Maximum score on the Concussion clinical knowledge metric as a function of values of the Δ-*t* Statistic. Model $F(2, 134) = 132.56$; $p < .0001$

# Structured Development of Interventions to Improve Physician Knowledge Retention

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## ABSTRACT

Military and civilian healthcare is undergoing radical transformations in almost every aspect of patient care from diagnosis to treatment. Along with increased complexity in the technology of delivery systems and procedures, medical knowledge is expanding at an ever-increasing rate, and yet clinicians are expected to retain knowledge and remain proficient in their fields. Frequency of exposure to specific clinical problems and processes are known contributors to physicians' decay of clinical knowledge and proficiencies. For example, while deployed, military physicians may experience less demand for specific clinical skills and are, therefore, at risk for knowledge decay. A systematically applied knowledge retention program integrated with continuous training is one possible response. However, institutionalizing standardized training at fixed intervals for all may not be the most cost-effective nor efficient solution. This paper discusses the progress of a research study tasked to develop and validate efficient interventions to mitigate physician knowledge decay that address both increased domain complexity and lower frequencies of exposure.

The process of intervention selection is based on the analysis of elements of the care for nine targeted clinical problems that reveal physician knowledge decay with decreasing frequency of exposure to those clinical problems. Once the most critical elements of the care process have been identified, we apply a structured approach for selecting, developing, and evaluating possible interventions geared towards choosing those that specifically address identified knowledge needs and align with the organization's learning goals, infrastructure and operating budgets. Recommendations for a systematic, yet flexible, method for evaluating, weighing and scoring multiple knowledge decay mitigation alternatives are included, supporting interventions ranging from static job aids to immersive learning simulations. In summary, this paper proposes a comprehensive selection model for continuing medical education programs committed to prevent skill decay, aid knowledge retention and improve overall physician and organizational performance.

## ABOUT THE AUTHORS

**Lloyd Werk, MD, MPH, FAAP** serves as Chief of the Division of General Pediatrics for Nemours Children's Hospital, leads its faculty and programs, and continues to practice pediatric medicine. Within the Nemours Office of Quality and Safety, he works with clinicians and researchers in health services research and quality improvement projects focusing on embedding metrics in the electronic health record, triggering just in time computerized clinical decision support, and providing feedback on clinical performance. Dr. Werk completed his undergraduate degree at Johns Hopkins University in Baltimore Maryland in 1983. He earned a Doctor of Medicine degree from Tel Aviv University in Tel Aviv, Israel in 1987 and a Master of Public Health degree with concentration in Epidemiology & Biostatistics from Boston University in Boston, Massachusetts in 1999. He completed a pediatric residency at Children's Hospital of Buffalo in Buffalo, New York, and practiced primary care pediatrics for several years on Long Island, New York, prior to completing a general academic pediatrics fellowship at Boston University in Boston, Massachusetts. He is an Affiliated Associate Professor of Pediatrics at the University of Central Florida College of Medicine. Dr. Werk serves as the Interventions Team lead in a DoD TATRC funded project investigating the maintenance of health care provider's clinical proficiency.

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## INTRODUCTION

Today, the healthcare field is undergoing radical transformations in almost every aspect of patient care. Medical knowledge is increasing so rapidly that it is virtually impossible for any health care provider to master it, digest new knowledge, or remember all that has been learned. Optimal maintenance and retention of physicians' clinical proficiency could reduce costs and enhance quality of care (Halm, Lee, & Chassin, 2002). Regretfully, **physicians cannot accurately assess their own knowledge proficiency** (Davis, Mazmanian, Fordis, Van Harrison, Thorpe, & Perrier, 2006). Within this environment and despite the best intentions of individual physicians, degradation of clinical knowledge and skills is inevitable, whether it is compared with one's initial knowledge base, the knowledge and skills of other physicians, or performance relative to published guidelines.

A knowledge retention program should address physicians' knowledge degradation as well as the requirement to continuously reevaluate and update their training and education programs. Yet, institutionalized training at fixed intervals may not be the most efficient nor effective solution for all physicians and healthcare organizations. Providing solutions based on when, where, and how to develop and deliver timely interventions is becoming as complex as the processes they are trying to improve.

This paper presents our findings in developing a structured approach to plan, develop, and evaluate physician education programs geared towards providing personalized, evidence-based interventions that align with the organization's goals, infrastructure, and operating budgets. It is an approach that considers different factors, such as: level of intrusion, feasibility, compatibility, interoperability, maintainability, and other related parameters. The intervention choices can range from simple cue cards/posters and other job aids to more sophisticated, immersive learning simulations. Examples of the types of interventions and knowledge retention programs considered include:

Training and Instruction Systems
- Human led instruction - such as lectures, workshops, video streamed sessions
- Static computer based training – e.g., online slideshow, online video
- Interactive computer based training - such as avatar/voice based, virtual instructor
- Simulation training – e.g., medical manikin, actor patients, scenario based, live demonstrations
- Individual feedback and mentoring

Job Aids and Performance Support Systems
- Visual aids – such as posters in exam rooms, checklists/flowcharts
- Computerized clinical decision support system - electronic health record embedded order sets, alerts, input template based tools

The selection of intervention may drive organizational courses of action, changes in healthcare system operations/daily business, and can even affect the way electronic medical record (EMR) data is processed in order to improve physician performance and patient outcomes. A key objective of our program of research is to develop efficient interventions to mitigate physician knowledge decay that address both increased domain complexity and lower frequencies of exposure. This paper presents preliminary project findings and assertions of research work that is in progress.

## TRAINING AND INSTRUCTIONAL SYSTEMS

The goal of a training or instructional course is to facilitate the act of learning to commit and retain information in long-term memory. The concepts and facts stored in long-term memory about a topic constitute knowledge. Instructional psychologists call this type of content declarative knowledge because it is easy to recall and articulate (Clark R. C., 2010). In the following sections, we discuss the current state of notable types of medical training and instructional programs.

### Continuing Medical Education (CME)

As noted two decades ago, didactic educational sessions such as courses, conferences, lectures, workshops, seminars, and symposia have little direct impact on competence, performance, and patient health status (Davis, Thomson, Oxman, & Haynes, 1995). Educational meetings can be made more effective by incorporating mixed interactive and didactic formats, and focusing on outcomes that are likely to be perceived as important (Forsetlund, 2009). Smaller interactive workshops can result in moderately large changes in professional practice (O'Brien, Freemantle, Oxman, Wolf, Davis, & Herrin, 2001). Delivery of these interventions at fixed times and locations may not reach the clinician who would most benefit from a refresher.

Increasingly, educational content is being delivered online to promote the retention and dissemination of medical knowledge during "teachable moments" when the learning is most immediately relevant to the physician. Advantages of this method include standardizing educational content that can be easily distributed to a geographically diverse population. Educators have the opportunity to regularly update, enhance and extend existing curriculum and learners can control the time and place of learning (Ruiz & Mintzer, 2006). Measuring and defining effectiveness of these educational interventions can be difficult, although knowledge and self-efficacy appear to be improved (Reed & Price E.G., 2005) (Stark, Graham-Kiefer, Devine, Dollahite, & Olson, 2011).

### Professional Certification

Since 2010, the US medical specialty boards have incorporated practice assessment and improvement as part of their requirements for ongoing professional certification. The process of maintenance of certification is intended to assure the public that physicians adhere to standards of continuous learning and assessment throughout their professional careers. There is growing evidence that participation in maintenance of certification programs focusing on promoting practice assessment and improvement positively impacts physicians' performance and their patients' outcomes (Gorzkowski, Klein, & Harris, 2014) (Vernacchio & Francis, 2014) (Wittich & Reed, 2014).

### Medical Simulation-based Learning

Simulation is commonly used throughout healthcare enterprises to enhance patient safety, education, and quality improvement. Simulation-based medical education provides an interactive hands-on training modality that bridges the gap between classroom learning and real life clinical experience. The use of simulation creates a safe, confidential learning environment that offers the participant the opportunity for deliberate practice followed by facilitated feedback and reflection on performance (Motola, Devine, & Chun, 2013). This supportive, encouraging, non-punitive environment allows learners to see the outcomes of their mistakes thus gaining powerful insight into the consequences of their actions and the need for improved performance (Ericsson, 2004).

At Nemours Healthcare System (NHS), simulation-based offerings are provided for attending physicians, fellows, residents, nurses, allied health care providers, non-clinical associates, patients and families. The goal is to enhance participants' technical, cognitive and behavioral skills as we improve quality of care, systems, processes, and spaces. In 2014, 6,588 participants completed 645 educational offerings in NHS. The medical simulation program has been used in training and ongoing refresher of training for response to medical emergencies. Additionally, an outreach program to primary care practitioners in a community setting engages physicians and their staff in responding to a child with an acute asthma attack, status epilepticus, and other clinical scenarios.

### Training and Instructional Intervention Choices

Table 1 below summarizes the key elements of the types of training and instructional systems that our research team considered in support of physicians' "maintenance" of knowledge pertaining to management of targeted clinical problems.

**Table 1. Training and Instructional Systems**

| *Type of Training Media* | *Description* | *Examples* |
|---|---|---|
| Human-led Training | Training delivered in the classroom, laboratory or video recorded media.<br><br>Clinical expertise growth through mentoring – protégé relationship | • Group sessions / workshops / lectures in classroom or conference room<br>• Thought experiment / open discussion<br>• Laboratory-based lesson or tutoring<br>• Video-streamed instruction or teleconference (live or pre-recorded)<br>• Feedback – by Peer or Supervisor |
| Basic Computer-based Training | Fixed learning content presented through a computer program or browser | • Online training modules or workbooks<br>• Slideshows or series of framed images in sequence to simulate animation |
| Interactive Computer-based Training | Computer based training that can present different content based on user inputs | • Web-based distributed learning<br>• Interactive courseware and testing<br>• Immersive 3D simulation<br>• Avatar/virtual instructor<br>• Virtual or augmented reality |
| Live Simulation Training | Live and simulation based medical training<br>Simulations of real events or imaginary scenarios | • Actor-based simulation (actor patients)<br>• Medical manikin<br>• Scenario-based live exercises<br>• Life-size immersive 3D visualization<br>• Live demonstrations |

## JOB AIDS AND PERFORMANCE SUPPORT SYSTEMS

In contrast to training and instruction systems, job aids and performance support systems are designed to assist a physician *while executing a clinical management task*. When applying job aids and performance support systems, organizations must provide concise information for the physician that is relevant to the execution of real time clinical care.

### Job Aids

Russell (1997) makes the distinction that there are three primary components of a job aid:

1. A job aid stores information or instruction external to the user.
2. A job aid guides the user to perform the task correctly.
3. A job aid is used during the actual performance of the task.

A job aid provides a visual cue to provide concise, relevant information at the point of care to augment physician memory (Willmore, 2006). It is important to point out that job aids are different from tools. A tool bypasses a physician's memory involved in executing a task or may complete a task automatically. That is, a tool does not store information that is to be remembered but facilitates performing a task. Since knowledge retention is not enhanced by tools, the consideration of tools as an intervention is not part of our study.

Clinical checklists are a form of job aids that have been adopted from the successful safety interventions developed to prevent pilot errors in the aviation industry. Simplified clinical checklists have been popularized by Dr. Atul Gawande, a surgeon and public health researcher (Gawande, 2010). Indeed, implementations by the World Health

Organization surgical safety and safe childbirth checklist programs for healthcare providers have shown to improve clinical outcomes and quality of healthcare (WHO, 2014). In another example, a simple checklist for the use of contact precautions for healthcare providers interacting with hospitalized patients resulted in a 40% reduction in the incidence of healthcare-associated Clostridium difficile infections (Abbett, et al., 2009).

**Electronic Performance Support System (EPSS)**

Computerized Clinical Decision Support Systems (CCDSS) are a form of EPPSS that provides clinicians, staff, patients or other individuals with knowledge and person-specific information, intelligently filtered or presented at appropriate times, to enhance health and health care. CCDSS encompasses a variety of tools to enhance decision-making in the clinical workflow. These tools include computerized alerts and reminders to care providers and patients; clinical guidelines; condition-specific order sets; focused patient data reports and summaries; documentation templates; diagnostic support, and contextually relevant reference information, among other tools (Clinical Decision Support, 2013). CCDSS can improve processes of care including diagnosis, management and the quality of documentation. CCDSS provide clinicians with computer-generated clinical knowledge and patient-related information, intelligently filtered or presented at appropriate times, to enhance patient care. Clinical decision support can help practitioners operationalize treatment guidelines. Key design features include what (information), who (recipient), how (intervention type), where (information delivery channel) and when (in the workflow). This framework constitutes the Clinical Decision Support Five Rights model (Osheroff, 2009).

In practice, adoption of a CCDSS can be challenging and can have unintended adverse effects (Singh, 2010) (Benin, 2011) (Eslami, 2006). Researchers at Nemours and Yale University found workflow constraints, technical expertise, impediments to communication, and applicability of clinical practice guidelines to medically complex patients were barriers to CCDSS use (Lomotan, 2012). Physicians commonly ignore CCDSS generated alerts about inappropriate medication prescriptions or medication combinations that could cause adverse drug reactions and CCDSS do not ensure timely follow-up of abnormal laboratory test results (Lin, 2008) (Raebel, 2007). In the United Kingdom, these types of lapses have been addressed through the combination of near universal use of electronic health records combined with CCDSS and substantial pay for performance incentives (Zhou, et al., 2009). The added practice of requiring practitioners to justify overriding CCDSS generated advice and providing the advice to both physician and patient appear to improve CCDSS effectiveness (Roshanov, et al., 2013) (Seidling, et al., 2011).

A primary goal of our research is that the selection of the intervention or intervention combinations is tailored to the specific body of knowledge to be retained. To do this, we need to consider a full complement of intervention choices. Table 2 summarizes the key elements of job aids and performance support systems considered for the study.

**Table 2. Job Aids and Performance Support Systems**

| *Type of Training Media* | *Description* |
|---|---|
| Visual Aids | Posters in exam rooms, checklists/flowcharts, etc.<br>• Posters and visual aids in exam rooms<br>• Posted checklists<br>• Lanyards, buttons, ribbons, badge cards with acronyms or other reminders |
| Electronic Performance Support System (EPSS) | Computerized Clinical Decision Support Systems (CCDSS)<br>• Check lists<br>• Order Sets / Smarts Sets<br>• Best practice alerts<br>• Template-based clinical documentation and forms<br>• Emails / text messages reminders |
| Online Coaching Material | Sequenced material on a mobile device or tablet or online movie/animation clips for coaching |

## HUMAN PERFORMANCE CONSIDERATIONS

A careful cognitive and human performance analysis requires evaluation of effective methods for improving human performance. The emphasis on improving human performance requires a new perspective for approaching and solving organizational performance requirements beyond limiting the solution to closing the knowledge and skills gaps through indiscriminant instructional solutions. Rather, evaluation of potential solutions should include consideration of non-instructional issues that affect the performance of individuals and teams in meeting organizational goals and objectives. These non-instructional factors can be barriers to realizing desired human performance outcomes and denigrate the effectiveness of an instructional solution if they are not identified and ameliorated. Examples of non-instructional factors include: the clinical setting, number of patient appointments per day, and on-call responsibility.

### Identification of Key Knowledge

For the study, we developed a standardized process that enabled us to evaluate each targeted clinical problem (TCP) comparably. The process applies a modified cognitive task analysis (CTA) to determine the specific clinical knowledge associated with each problem. This involved a review of published clinical practice and Nemours Healthcare System organizational guidelines combined with interviews with clinical specialists and experts. The modified CTA focused knowledge elicitation on identifying the key declarative knowledge associated with diagnosing, treating and reporting the clinical condition in the EMR.

### Knowledge Metrics from Electronic Medical Records Data

Knowledge identified during the interview and subsequent analyses were used in a review of the EMR data "dictionary" to identify fields that corresponded to the required knowledge determined by the CTA. In addition, queries were written and executed to locate expressions of required declarative knowledge in EMR free-form text fields such as progress notes and patient information.

### Knowledge Utility Function and Fit Decay Model

Queries extracting knowledge metrics from physician free-form text logs and other EMR fields were combined into a multivariate knowledge utility function (KUF) and exercised against a database of historical patient encounters to establish a knowledge decay model represented by Equation 1:

$$\boldsymbol{K}(\Delta \boldsymbol{t}) = \boldsymbol{e}^{-\boldsymbol{\gamma t}} \qquad (1)$$

where $t$ is time since previous encounter, $K(\Delta t)$ is the KUF value where $\gamma$ is the vector sum of weighted individual differences and e is Euler's constant. The cognitive sciences recognize this as an application of the Ebbinghaus knowledge retention model (Ebbinghaus, 1999). The time since last encounter applied in the equation above, with the individual gamma value produces a predicted knowledge level K(t). When that forecasted level drops below a set point at an associated $\Delta t$, we trigger a need for a targeted intervention. The threshold is determined through recommendations from subject matter experts for each type of clinical problem. Note that this approach does not differentiate between the levels of experience of the practicing physicians.

## SELECTION OF INTERVENTIONS BASED ON CONDITION

Over the course of a year, a multidisciplinary team consisting of physicians, educators, social scientists, health informaticists, information systems experts, researchers and administrators met in person thrice with six interim teleconference meetings to determine a structured approach for planning, developing, and evaluating possible interventions to mitigate knowledge decay and promote retention. Key determinants of intervention selection were found to be the primary knowledge elements within each condition to be addressed and decisions around development of training and instruction systems versus job aids and performance support systems. When developing interventions in anticipation of knowledge decay or at the point of care to mitigate an unmet information need, we considered several factors following guidelines suggested by Russell (1997):

- Frequency of knowledge recall - Frequent versus infrequent condition encounters, medical seasonality – e.g. influenza or bronchiolitis in the winter; scoliosis identification with annual school physical examination
- Complexity - Multiple or few decision points, extent of body of knowledge – e.g. determining appropriate management of gastroesophageal reflux.
- Frequency of clinical procedure information change – e.g. influenza vaccine protocols vary from year to year
- Consequence of error and error proneness – Criticality of committing and likeliness of negative results - e.g. determination of nerve impingement in supracondylar fracture reduction
- Work environment and variety of locations related to point of care - e.g. saturating work surfaces and walls with brief reminders would likely be ignored or may not be feasible in all locations

As we apply the *knowledge utility function (KUF)*, a cause analysis is performed to determine the type of knowledge decay for selection of intervention. We determine if the lack of performance is due to a deficiency in environmental support, e.g. data, information and feedback or a lack of repertory of skills and knowledge and individual capacity. If the necessary knowledge can be presented effectively in the environment, a job aid is recommended. If the exercise of knowledge must be performed *in situ* with little time to consult a job aid or at different locations, then training is indicated. The breadth of knowledge required in the medical profession must also be considered. A multitude of job aids can quickly become a hindrance to performance. Our recommended intervention selection flow is summarized in Figure 1.

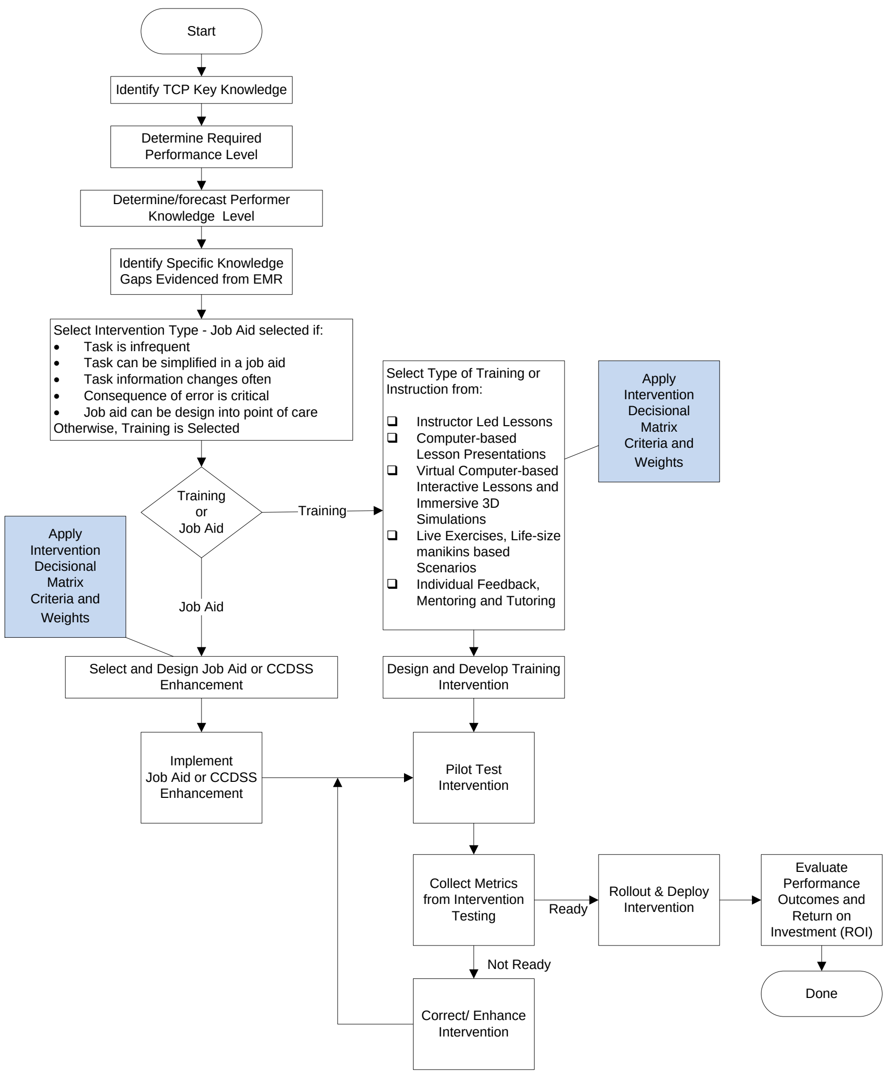


**Figure 1. Intervention Selection Flow**

The research team developed a systematic process with the objective of ensuring that the intervention type selected to improve care for each of the targeted clinical problems are matched to empirically identified needs. This process employs several sequential stages for each targeted clinical problem including the review of existing EMR data, stakeholder surveys, focus groups and pilot testing explained as follows:

1. **Review of Existing EMR Data for Metrics**

The team reviewed existing EMR data to specify elements of the optimal care process for each targeted clinical problem (TCP) in search of metrics that tend to demonstrate decay in association with increased values of the $\Delta$-t statistic. For each TCP, the team fitted a multivariate model that included characteristics of the worker (e.g., title, department, specialty, proficiency of EMR utilization), characteristics of the workplace (e.g., clinical setting, number of patient appointments/day, on-call responsibility) as predictors of decline/maintenance of clinicians' decision making proficiency as a function of the $\Delta$-t statistic. This multivariate modeling is used to identify individual health care providers who may be most prone to clinical skill decay and to guide the team's selection of specific EMR data elements that will become intervention foci.

2. **Establish Criteria using Stakeholder Surveys**

Stakeholders (physicians, health informaticists, administrators, researchers, educators and information systems experts) were asked to complete a survey to quantify their perspectives of ten dimensions that characterize any intervention (feasibility, intrusiveness, effectiveness, cost, development time, compatibility, scalability, interoperability, extensibility, maintainability). Among 40 stakeholders there was a clustering of responses in a 5 choice Likert scale which were further collapsed to three weights (High, Medium, and Low) and assigned as shown in Table 3.

**Table 3. Intervention Decisional Matrix with Stakeholder Weights**

| Domain | Criteria Questions (Scored 1-5 points) | Weight |
|---|---|---|
| Feasibility | 1) How feasible is the intervention in the current work environment? | High |
| Intrusiveness | 2) How intrusive would the intervention be in the current work flow? | High |
| Effectiveness | 3) What is the anticipated effectiveness of the intervention in mitigating knowledge decay based on comparative efforts? | High |
| Cost | 4) What is the relative cost to develop, test and deploy? | Medium |
| Schedule to Complete | 5) What is the estimated time to establish the intervention? | Medium |
| Compatibility | 6) Is it compatible with current intervention approaches or incompatible / orthogonal with current practice? | Medium |
| Interoperability | 7) Can the intervention be integrated/connected with another intervention? | Medium |
| Scalability | 8) Can the approach be supported enterprise-wide or limited to specific practitioners or clinical locations? Can intervention be deployed to other sites? | Low |
| Extensibility | 9) Does the approach consider future growth, future plans, and technology advancements? How tightly coupled and limited is it to current technology capability? | Low |
| Maintenance | 10) What is the estimated effort and cost to maintain and sustain over the lifecycle? | Low |

Table 3 shows the criteria established by the research team to reach a final recommendation for training or job aids as a targeted intervention. Interventions are scored on a scale of 1 to 5 points based on how well they satisfy the *desired* answers (e.g., a highly intrusive intervention receives a low score of 1, versus a low level of intrusion receives a 5).

It is important to note that these criteria should be applied to job aid selections *independently* from training selections. If the selection is made combining job aid and training choices, then a job aid is usually the preferred intervention since they usually can be developed at a lower cost, in shorter development time frame, with little intrusiveness and a quicker worker adoption time. Decision makers need to ensure that the criteria do not create a bias that impedes the selection of training interventions when they are necessary.

It is likely the priorities of stakeholders in aggregate and individually may vary by institution which would impact on the weights assigned. It was remarkable the high degree of alignment at this one health system. Proposed interventions were then applied to this decisional matrix and stakeholders rank-ordered their responses. Note that the criterion is expanded to include non-instructional considerations such as cost, schedule, scalability, extensibility and maintenance.

3. **Establish Focus Groups**

Conducting Focus Group meetings with stakeholders (health care providers representing affected clinical divisions) helped the research team to refine their perspectives on relative weighting of elements of intervention planning decisions for each targeted clinical problem, to select from among intervention options with similarly positive stakeholder ratings, and to combine available options into multi-component interventions. Acquiring and using detailed stakeholder perspectives is critical to ensuring that intervention methods are selected and developed by health care providers for health care providers rather than being imposed upon them by others who lack a detailed appreciation for the complex contexts in which sophisticated health care decisions are made.

4. **Perform Pilot Testing**

Pilot testing of intervention methods helps the research team to obtain preliminary estimates of the intervention's feasibility, acceptability and efficacy, to refine the intervention accordingly and to obtain experience with it before rolling it out more broadly. Limited experience with implementation of the selected interventions before a larger-scale rollout will enable the research team to identify and resolve potential problems, clarify any ambiguities about implementation and confirm the capacity to evaluate intervention outcomes empirically.

## EVALUATION OF INTERVENTIONS

### Assessment of Knowledge Transfer

In evaluating the effectiveness of interventions to mitigate knowledge decay, the classic evaluation model would propose four levels: reaction, learning, behavior, and results of evaluation (Kirkpatrick D. L., 1998).

- *Reaction* - How well did the learners like the learning process?
- *Learning* - What did they learn? What is the extent to which the learners gain knowledge and skills?
- *Behavior* - What changes in job performance resulted from the learning process? What is the change in capability to perform the newly learned skills while on the job?
- *Results* - What are the tangible results of the learning process in terms of reduced cost, improved quality, increased production or increased efficiency?

Post intervention learner interviews will enable evaluation of *reaction* to the intervention. We plan to include this throughout the intervention development phases. Likewise, training interventions will include an immediate assessment of *learning*. Evaluation of *behavior* and *results*, including learning transfer will be obtained using post-intervention EMR data entries over the period of the study.

### Measurements from EMR Data

Based on knowledge retention analytics from the EMR, we propose to assess the following performance indicators:

1) Sustained knowledge retention and performance proficiency in application of the intervention and learned material to the physician's immediate job.
2) Consistency in the expression and utilization of key declarative knowledge.
3) Generalization and adaptation of learning to jobs or tasks not originally anticipated by the training, but related in a way that allows the learning effects to multiply.

Measurement of individual sustained performance utilizes the same EMR queries and metrics used to develop the learning retention model. We anticipate a return to standard immediately after training or on-the-job intervention. Consistency in knowledge expression should also stabilize as a result of intervention as it is exercised prior to a forecast knowledge decline. We expect to see a reduction in the standard deviation of the aforementioned metrics in those departments where the intervention is deployed as compared to departments without the intervention.

Metrics based on EMR data for each of the selected conditions were developed. Since we propose to perform analysis on multiple targeted clinical problems (TCP), we may be able to observe generalization effects of improved expression of knowledge with the other clinical conditions. In departments where an intervention is applied, effects may be observed in metrics for the specific condition, as well as for other conditions due to a crossover effect.

## DISCUSSION

This paper describes preliminary research experiences in developing and implementing a systematic strategy for the selection, implementation and evaluation of interventions designed to prevent, minimize or mitigate decay in physicians' clinical declarative knowledge. We propose interventions can be triggered based on the frequency of exposure to the TCP of interest modified by clinician and workplace environment. The EMR will serve as a source for detecting risk for knowledge decay by recording TCP exposure and presence or absence of key clinical data elements. Downstream, the EMR can be a source of subsequent effects of clinical care processes and outcomes.

For physician assessments, we should caution about solely using knowledge as expressed in the EMR as a measure of clinical performance. The application of declarative knowledge is a key element of performance, and the EMR is limited in its capability to indicate the presence of such knowledge. The records do not indicate when the knowledge was applied by the physician if it was not or cannot be recorded in the EMR. Interpretations of performance and intervention effectiveness should be understood in light of these limitations.

An important distinction is made when selecting interventions that are *job aids* versus *training and instructional programs*. Ideally, most instances of knowledge decay would be mitigated with job aids, since these tools can supplement clinical knowledge at the point of care. Job aids in the form of check lists have been a huge success in improving performance and patient outcomes. However, healthcare organizations need to consider task complexity, frequency of change and the operating environment when selecting between job aids and training interventions. These factors help determine whether the perceived knowledge decay should be *remediated on the job* or *committed to memory* via training.

Interventions in medical training and operations have an ultimate goal of improving the quality and safety of health care in a cost effective manner. One concept to be explored by our team will be to utilize the EMR to trigger just in time, proactive interventions knowing that this approach is limited to database content. In the future, peak physician performance will require training & instructional systems and job aids & performance support systems that dynamically adapt as new evidence emerges, provide personalized support that recognizes the clinician's background and experience, and tailor recommendations based on specific patient characteristics. Interventions may also be customized and scaled in intensity to accommodate a wide range of learners from novices to experience. The expectation is that *just-in-time, tailored interventions* will help clinicians not only gain and assess critical knowledge, but also increase confidence and attain enhanced focus when encountering more complex and demanding aspects of patient care.

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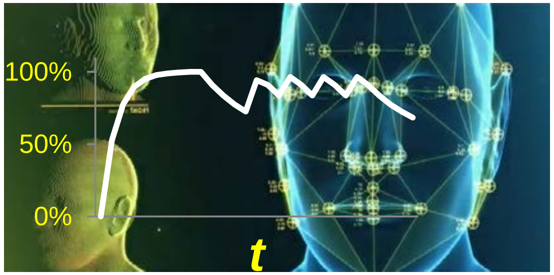


# Validation of cognitive performance measurements to map physician declarative knowledge in practice

## WG20: #11983 DWG1: #12329

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Nemours. Children's Health System

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# Topics

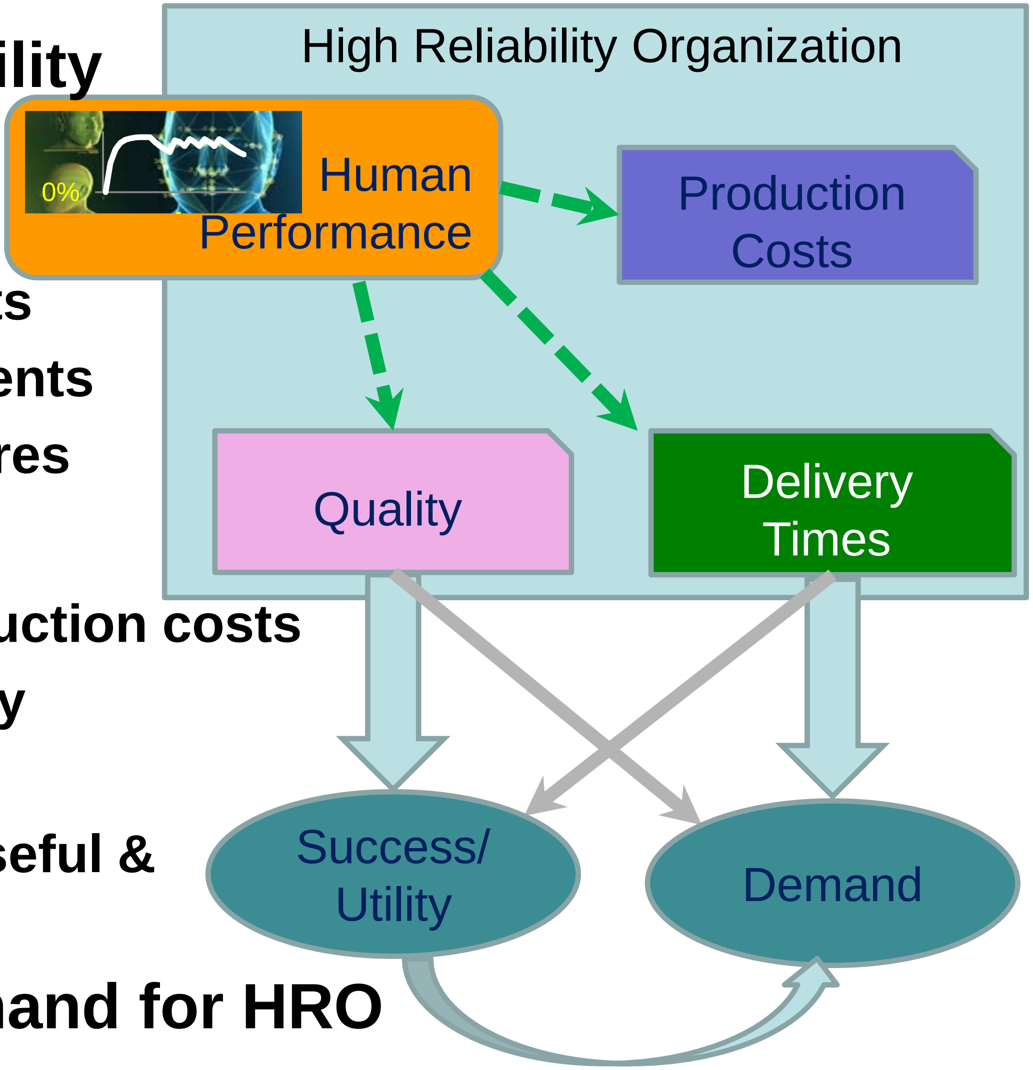
- Need For Cognitive Performance Models
- Theory of Declarative Knowledge Sustainment
- Declarative Knowledge Modeling
- Measuring Knowledge Retention
- Findings
- Application

# ***Need for Cognitive Performance Models***

# Need for Cognitive Performance Models

## *A Management Requirement*

- **Successful High Reliability Organizations (HRO)**
  - ✓ **Maintain quality**
  - ✓ **Control production costs**
  - ✓ **Meet delivery commitments**
  - ✓ **Learn from error & failures**
- **HRO managers**
  - ✓ **Predict & controls production costs**
  - ✓ **Monitor & control quality**
  - ✓ **Predicts delivery times**
  - ✓ **Consistently delivers useful & quality products**
- **Success increases demand for HRO**




***Establishing & Keeping the HRO effective requires performance models***

# Need for Cognitive Performance Models

## *A Science Problem and an Art – Models provide the Science*

- **Knowledge is <u>dynamically</u> dependent on internal & external processes**
  - ***Knowledge is <u>not</u> a constant***
  - ***Knowledge varies individually across time***
  - ***<u>Time is a proxy for unobserved processes</u> (e.g. forgetting)***
  - ***It varies between individuals across the organization***
- **Knowledge requirements change through time as well**
  - ***Technology requires new knowledge***
  - ***Science & discovery produces new knowledge***
  - ***Standards of practice change***
- **Planning with anticipation of knowledge readiness**
  - ***Enables decision making based on realistic assumptions***
  - ***Helps plan <u>affordable training/retraining schedule</u>***
  - ***Helps avoid costly errors & maintain overall quality***
- **Enabler for organizational performance monitoring**
  - ***Model provides assessment metrics***
  - ***Model identifies realistic performance level & expectations***
- **Cognitive performance models help focus maintenance of HRO**
  - ***identify potential areas of failure***
  - ***clarify complex processes and avoid oversimplification***
  - ***emphasize total system interdependency and operation***
  - ***provide analysis of alternative solutions providing resilience under adverse situations***
  - ***identify key sources of critical information and who has necessary expertise***

***Scientific performance models enhance critical decision making***

# *Theory of Declarative Knowledge Sustainment*

# Theory of Knowledge Sustainment

- Background Research
- Types of Knowledge & Performance
- Classes of Performance Capabilities
- A Learning Curve Model
- A Knowledge Decay Model
- Knowledge Decay Factors
- Partitioning the Knowledge Sustainment Model

# Theory of Knowledge Sustainment

## *Background Research*

- **Cognitive Psychology**
  - ***Andersen, J. R., Fincham, J. M., & Douglass, S. (1999). Practice and Retention: A Unifying Analysis. Journal of Experimental Psychology, Learning, Memory and Cognition , 1120-1136.***
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# Theory of Knowledge Sustainment

## *Background Research (continued)*

- **Human Performance Technology**
  - ***Arthur, Jr., W., Bennet, J. W., Stanush, P. L., & McNelly, T. L. (1998). Factors that influence skill decay and retention: A quantitative review and analysis. Human Performance , 57-101.***
- **Skills Deterioration Symposium**
  - ***O'Neil & Rivera (2011) Educational Psychology and Human Factor Issues Involved in Studying (or Evaluating) Degradation of skills***

## DOD Research *(many articles)*

- **Air Force Research Laboratory**
  - ***Andrews, D. H., & Fitzgerald, P. C. (2010). Accelerating Learning of Competence and Increasing Long-Term Learning Retention. Mesa, AZ: Air Force Research Laboratory/RHA, Warfighter Readiness Research Division***
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# Theory of Knowledge Sustainment

## *Types of Knowledge & Performance*

- **Declarative Knowledge**
  - *Defines what knowledge is needed for performance*
  - *Is Abstract, often described as book knowledge*
- **Procedural Knowledge**
  - *Sequencing of actions*
  - *When is order important and not important*
  - *Performance outcome interdependencies*
- **Visual-Psychomotor Abilities (VPA)**
  - *VPA skills acquired/retained through practice*
  - *Learning pedagogies and practice builds:*

| | | |
|---|---|---|
| • Accuracy | • Speed | • Quality |
| • Endurance | • Strength | • Fluency |

- **Attitudes & Affect**
  - *Identifies relative importance of performance effects*
  - *Enables response agility when external conditions change*
- **Team/Leadership**
  - *Team Resource Management*
  - *Emotion Management*

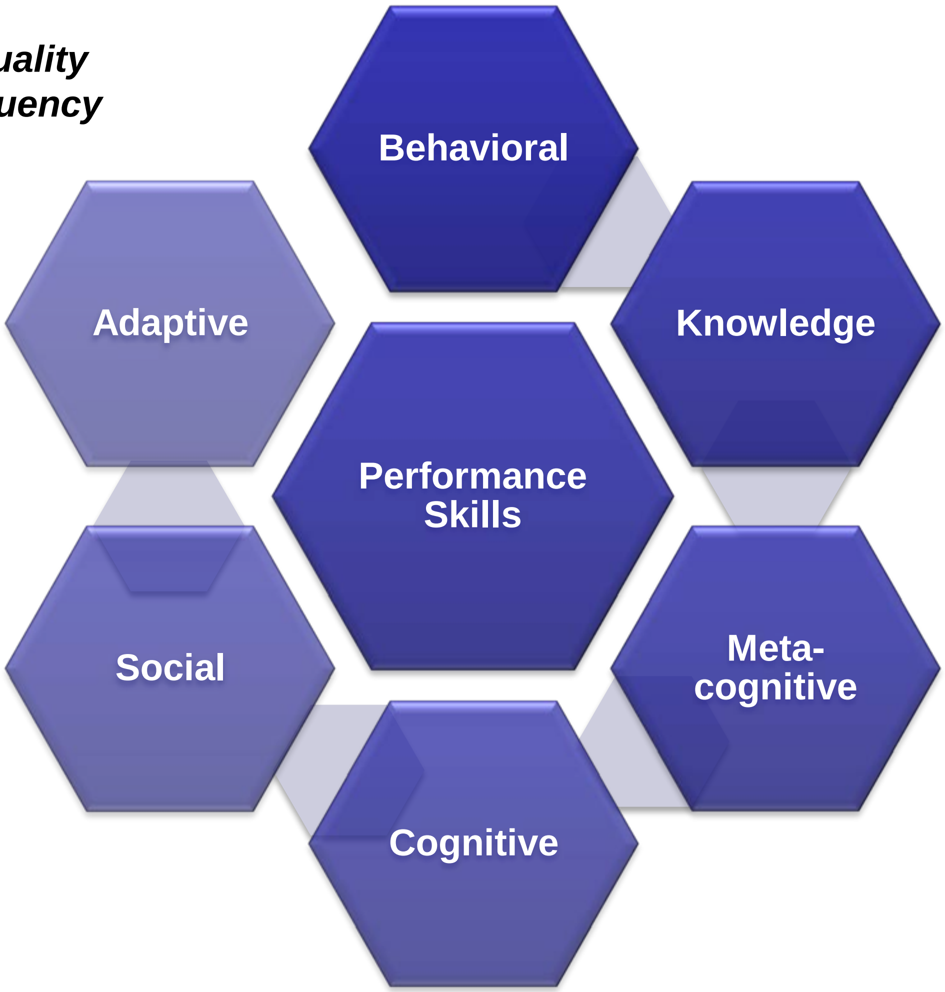
**Study Focus**

***Skill retention is complex and requires multiple brain physiologies***

# Theory of Knowledge Sustainment

## *Classes of Performance Capabilities*

- **Behavioral**
  - *Accuracy*
  - *Endurance*
  - *Speed*
  - *Strength*
  - *Quality*
  - *Fluency*
- **Knowledge**
  - *Memory*
  - *Memory Aids*
- **Metacognitive**
  - *Self Monitoring*
  - *Self Respect & Confidence*
  - *Honest Self Appraisal*
- **Cognitive**
  - *Awareness*
  - *Sensemaking*
  - *Focus & Flow*
  - *Decision making*
- **Social**
  - *Leadership*
  - *Coordination*
  - *Language & Culture*
  - *Influence*
  - *Communication*
- **Adaptive**
  - *Science, Technology & Discovery*
  - *Performance Standard Changes*

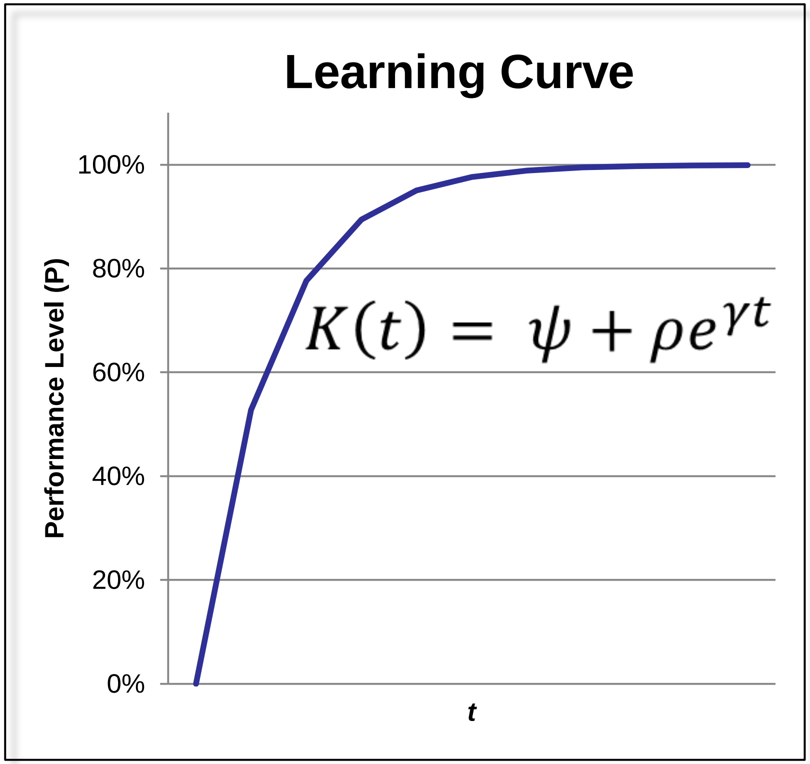



***Knowledge retention assessment must be multidimensional***

# Theory of Knowledge Sustainment

## *A Learning Curve Model*

- **Subject Matter**
  - ***Declarative Knowledge Requirements***
  - ***Procedural Knowledge Requirements***
  - ***Visual-Motor Skill Requirements***
  - ***Required Level of Abstraction***
  - ***Decision Making Process & Support***
  - ***Team / Collaboration Requirements***
- **Learner**
  - ***Intellectual Development***
  - ***Emotional Intelligence***
  - ***Meta-cognitive Skills***
  - ***Prior Experience***
  - ***Perception of Content Relevancy***
- **Instructional**
  - ***Pedagogy***
  - ***Media***
  - ***Environment***



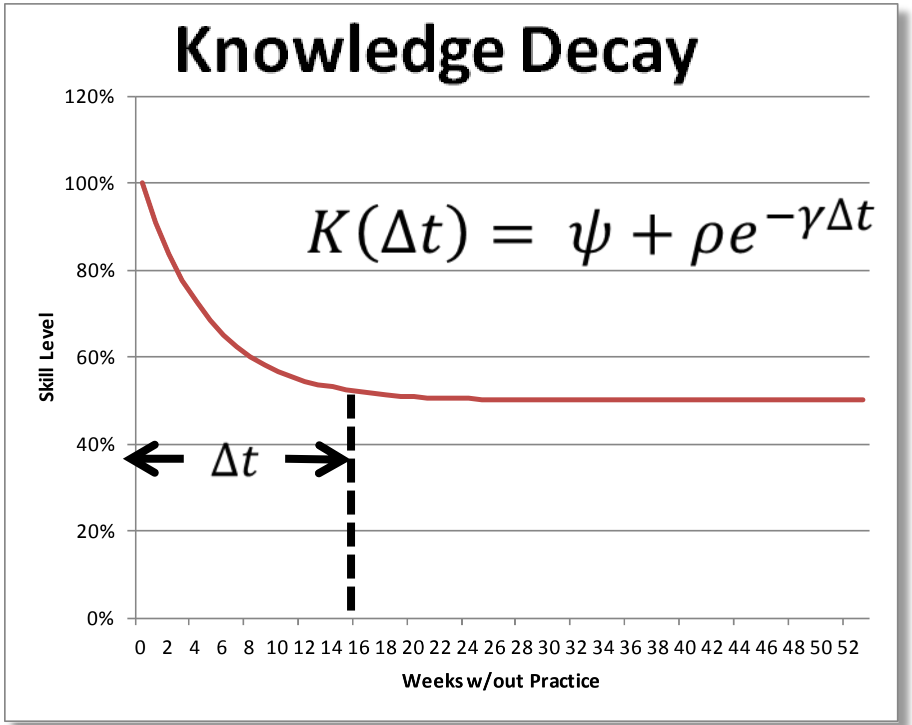

*$\psi$ = Maximum knowledge level*
*$\rho$ = Knowledge metric scaling factor*
*$\gamma$ = Knowledge decay shape factor*
*$K(t)$ = Knowledge at time $(t)$ = $\psi + \rho e^{\gamma t}$*

***Learning can be expensive – Modeling helps optimize that investment***

# Theory of Knowledge Sustainment

## *A Knowledge Decay Model*

- **Knowledge decays as a function of time between remembrances ($\Delta t$)**
- **Conversely, some knowledge will not decay**
  - ***Knowledge specific decay may be a function of:***
    - **Availability Job Aids**
    - **Frequency of remembrance**
    - **Similarity to unrelated tasks**
    - **Knowledge acquisition age or technique**
  - ***Need to identify knowledge that does not decay***
- **Actual knowledge performance will be observed as a multivariate Knowledge Utility Function (KUF)**




$\psi$ = Minimum knowledge level

$\rho$ = Knowledge metric scaling factor

$\gamma$ = Knowledge decay shape factor

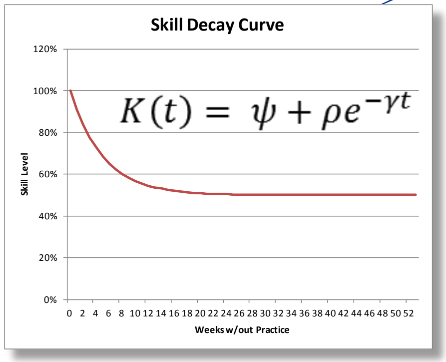
$K(\Delta t)$ = Knowledge at time since last encounter

***KUF obtained from observed performance data***

# Declarative Knowledge Modeling

# Declarative Knowledge Modeling

## *Model Development Requirements*




- **Select Targeted Clinical Problem(TCP)**
  - ***Identify relevant clinical conditions***
  - ***Select a subset of clinical conditions for study***
  - ***Identify knowledge data sources for these problems***
- **Construct Skill Retention Model (SRM) for TCP**
  - ***Cognitive Task Analysis (CTA) to identify Knowledge, Skills & Attitudes (KSA) for TCP***
  - ***Work Performance Metrics***
    - **Mine Electronic Healthcare Record (EHR) system for knowledge indicators**
    - **Construct performance Metric(s) for TCPs**
    - **Identify confounding concepts & develop control covariates**
      - ***CTA EHR utilization***
      - ***CTA workplace considerations***
  - ***Worker Metrics***
    - **Training & experience**
    - **General Abilities**
  - ***Workplace Metrics (external considerations)***
- **Use CTA & SRM with EHR to develop retention intervention solution**

***Skills retention is a function of the work, the worker and the workplace***

# Declarative Knowledge Modeling

## *Model Development Process – Evidence-Based Modeling*

- **Key characteristics a linear function of:**
  - *Task characteristics*
  - *Learner capabilities*
  - *Instructional modes*
  - *Performance Environment*
  - *Non-performance environment*
- **Define metrics for performance analysis**
- **Create Measurement & Assessment Instrumentation**
- **Data collection**
- **Model Parameterization Non-linear Estimation techniques**
  - *SPSS, SAS, Jump, R & MATLAB statistical packages support technique*


***Readiness estimation through Evidence-Based Modeling***

# Measuring Knowledge Retention

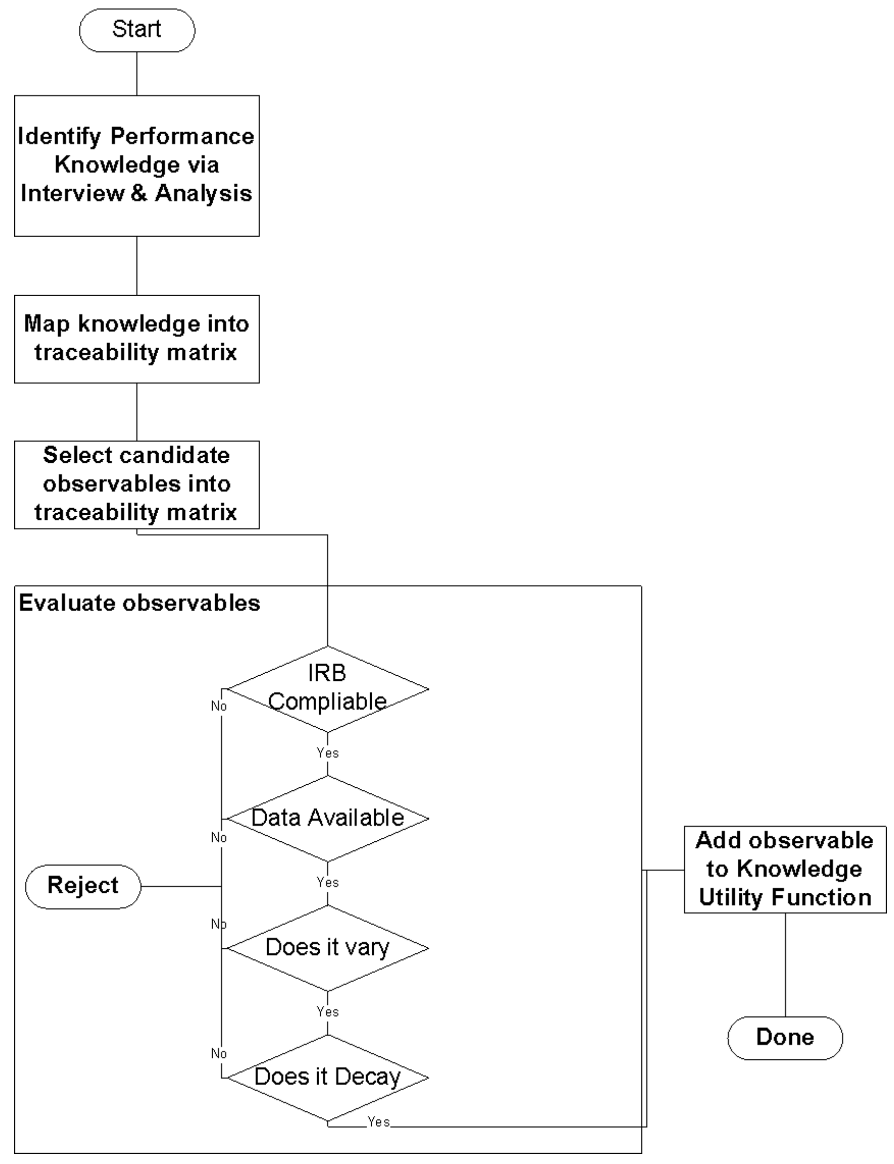
# Measuring Knowledge Retention

- **Knowledge Utility Function (KUF) Development**
- **KUF – Institutional Review Board (IRB) Compliance**
- **KUF – Data Dynamic Variation**
- **Model Analysis KUF construction**

# Measuring Knowledge Retention

## *Knowledge Utility Function (KUF) Development*

- **Determine usable data from the EHR**
- **Start with expert identified knowledge**
- **Scan EHR dictionary for relevant data**
- **Evaluate the observable**
  - ***Is it IRB compliable?***
  - ***Does it have any or sufficient data?***
  - ***Does it vary in our population?***
  - ***Does it vary according to performance time gap?***



# Measuring Knowledge Retention

*KUF – IRB Compliance*

- **Metrics derived from EHR are most readily manipulated into IRB compliance**
  - ***Identity masking, using randomized global unique ID (GUID)***
  - ***Event time masking by giving time as offset from undisclosed start time***
  - ***Data grouping (e.g. transform interval data into ordinal quartiles)***
  - ***Excluding data from study that are not compliable***
- **Individual Metrics based on other sources**
  - ***Physician's Pulse***
    - **EMR skills & utilization**
  - ***Meaningful Use***
  - ***Echo credential database***
    - **Academic credentials**
      - ***Data grouping w/ published school ranking***
      - ***School location-State/non-US***
    - **Country of Origin**
    - **Language skills**

# Measuring Knowledge Retention

*KUF – IRB Compliance*

## *Requires IRB approval for use...*

- **Metric enables identification of specific patients**
  - ***Describes identifiable characteristic of specific patients***
  - ***Observed  only during events of a very unique nature***
  - ***Describes existing or results in outcome conditions or treatments of unique nature***
- **Metric enables identification of specific physicians or other medical practice caregivers**
  - ***Uses specifically unique skills of identifiable physicians***
  - ***Observed only during events of a very unique nature***
  - ***Describes existing or results in outcome conditions or treatments of unique nature***
- **Metric is intrusive, causing direct harm to physician or patient**
  - ***Even metrics derived from existing EHR or other sources can be intrusive in their effects***

# Measuring Knowledge Retention

*KUF – Data Dynamic Variation*

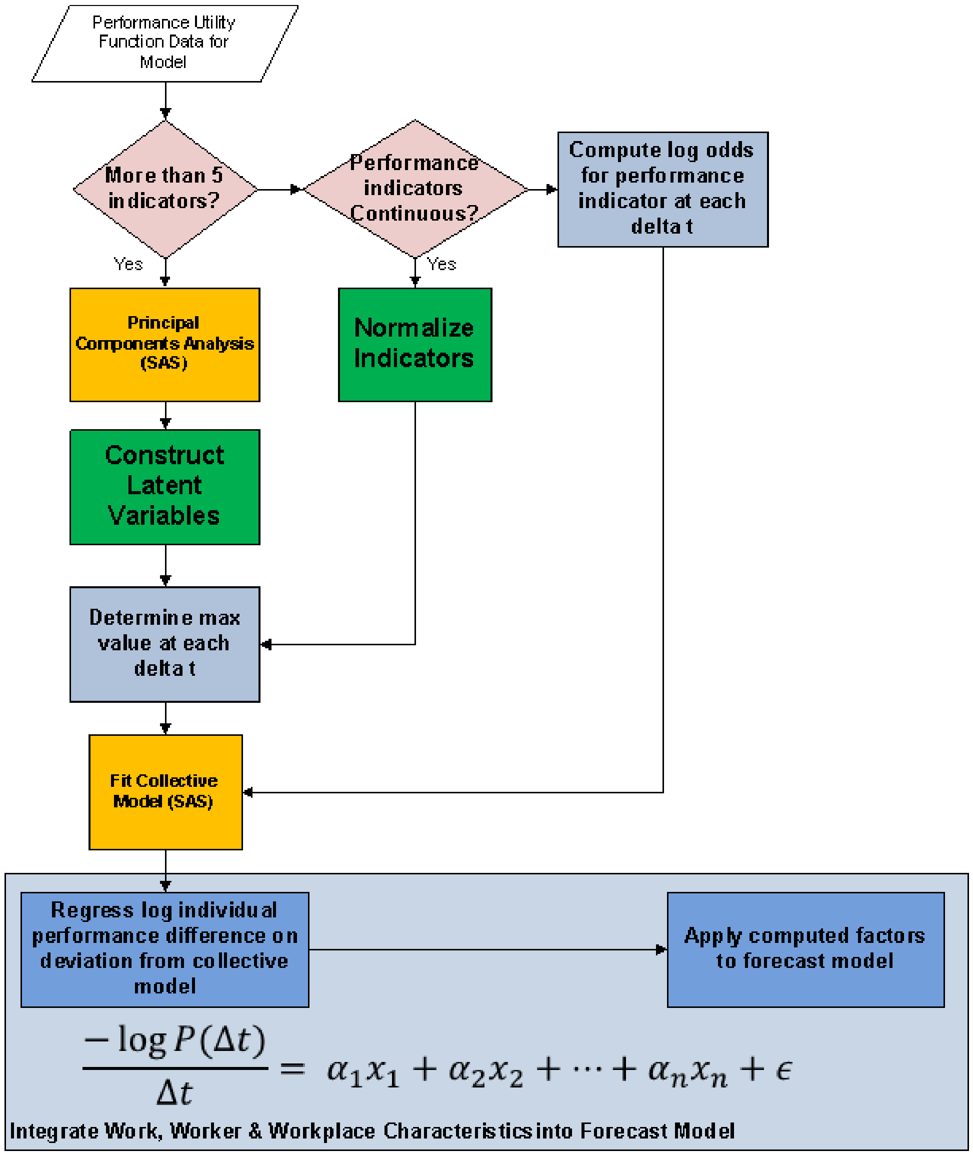
## *Not usable if...*

- **Data has no variation in performance frequency ($\Delta t = 0$)**
  - ***Event data occurs frequently for all physicians***
  - ***Event rarely occurs***
- **Data does not show decay over time**
  - ***Performance is not time varying***
  - ***Performance varies greatly at all times, including time "0"***
- **Data is missing for some, e.g. $\Delta t >$ some value**
  - ***Right censoring due change in data recording process***
  - ***Left censoring due to limits of recording process***
  - ***Systematic missing clustered along caregiver attributes***

# Measuring Knowledge Retention

## *Model Analysis KUF construction*

- **Determine if performance data can be made continuous**
  - ***Use Principal Components Analysis to construct latent variables***
- **If small number of continuous indicators normalize and use them**
  - ***Determine Max value of indicator(s)***
  - ***Fit NLM to max value***
- **If indicators dichotomous, transform to log odds and fit NLM to value.**
- **Regress on individual factors**
- **Apply computed weights to forecast model**

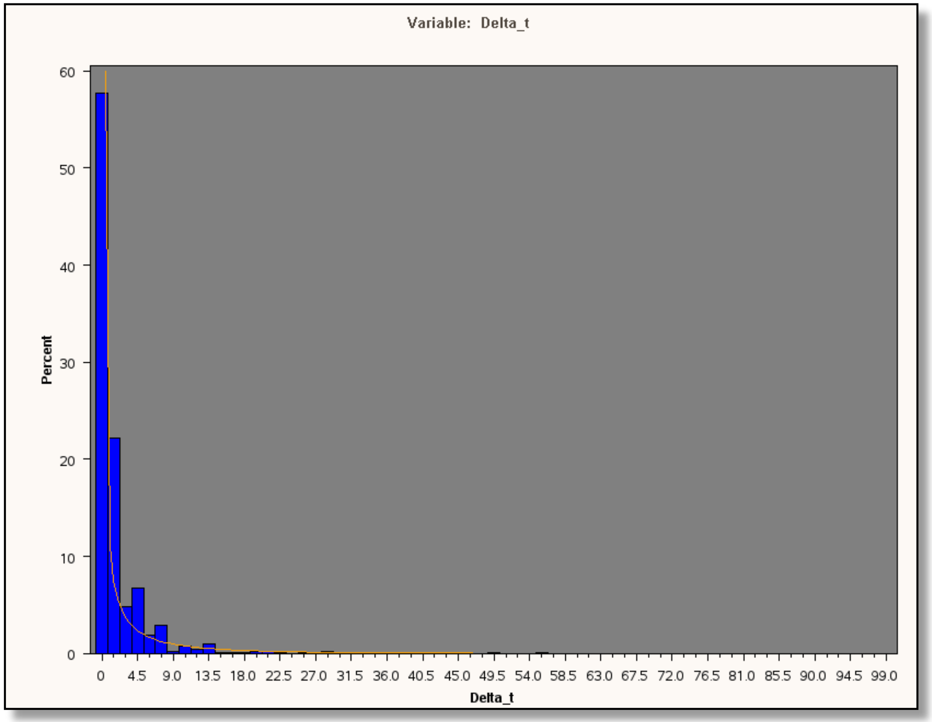


# Findings

# Findings

## Observed Obesity Encounter Rates at $\Delta t$

- **Sample taken from patient encounters during 2013**
- **Obese defined as Body Mass Index (BMI) > 95th percentile**
- **Across Nemours system, 90278 encounters with obese patients**
  - ***Patient seen for variety of reasons***
  - ***BMI always computed***
- **$\Delta$t ranged from 0 to 285 days**
- **57.76 % occurred on same day as previous obese patient encounter**
- **Curve is a gamma fit**
  - ***implies a constant arrival rate of obese patients***
  - ***As expected, arrivals occur frequently***
  - ***Note presence of cases of $\Delta$t greater than two weeks***



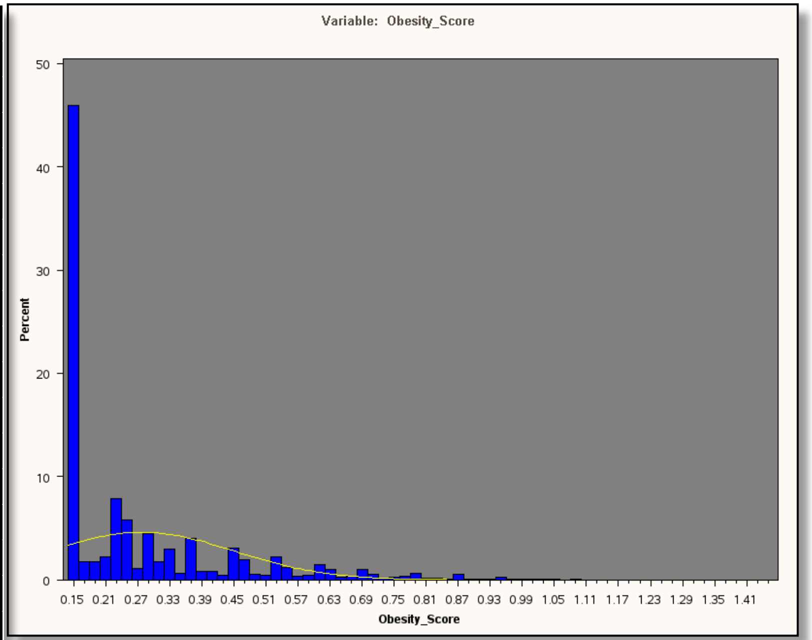
# Findings

## Knowledge Utility Function (KUF) computation

- **Uses 17 factors queried from EHR**
- **Factors weighted by Eigenvalue and summed to produce Obesity score**
- **Normalized Obesity Score**
  - ***Mean: 0.277753, Standard Dev: 0.17308, Min: 0.156525 Max: 1.45215***

| Basic Statistical Measures | | | |
|---|---|---|---|
| Location | | Variability | |
| **Mean** | 0.277753 | **Std Deviation** | 0.17308 |
| **Median** | 0.210812 | **Variance** | 0.02996 |
| **Mode** | 0.156525 | **Range** | 1.29563 |
| | | **Interquartile Range** | 0.17314 |

| Concept | Variable Name | Mean | Standard Dev | Eigenvector |
|---|---|---|---|---|
| Diagnoses Obesity | C_Obesity_DX | 0.329 | 0.607 | 0.4000 |
| Noted Family history of Obesity | C_Obesity_FamHX_DX | 0.009 | 0.113 | 0.1004 |
| History of Obesity | C_Obesity_HX_DX | 0.002 | 0.049 | 0.0019 |
| Notations on abdominal pain | C_Abdom_Pain | 0.058 | 0.276 | 0.0079 |
| Notations on snoring | C_Snoring | 0.095 | 0.342 | 0.1619 |
| Notations on apnea | C_Apnea | 0.056 | 0.266 | 0.0947 |
| Notations on anxiety | C_Anxiety | 0.063 | 0.293 | 0.0338 |
| Notations on social isolation | C_Soc_Iso | 0.002 | 0.049 | 0.0255 |
| Notations on activity intollerance | C_Act_Intol | 0.004 | 0.074 | 0.0760 |
| Notations on school avoidance | C_School_Avoid | 0.004 | 0.071 | 0.0174 |
| Notations on school phobia | C_School_Phobia | 0.005 | 0.080 | 0.0214 |
| Notations on shortness of breath | C_Short_Breath | 0.004 | 0.068 | 0.0329 |
| Notations on sleepiness during day | C_Day_Sleepy | 0.003 | 0.064 | 0.0413 |
| Advised 521 nearly none | C_521 | 0.154 | 0.496 | 0.3740 |
| Noted obseity in notes | C_Obese | 0.261 | 0.452 | 0.5311 |
| Advised Weight Management | C_Wt_Mngmnt | 0.080 | 0.300 | 0.4334 |
| Advised Exercise | C_Exercise | 0.285 | 0.571 | 0.4167 |



# Findings

## Observed Obesity Diagnosis Scores

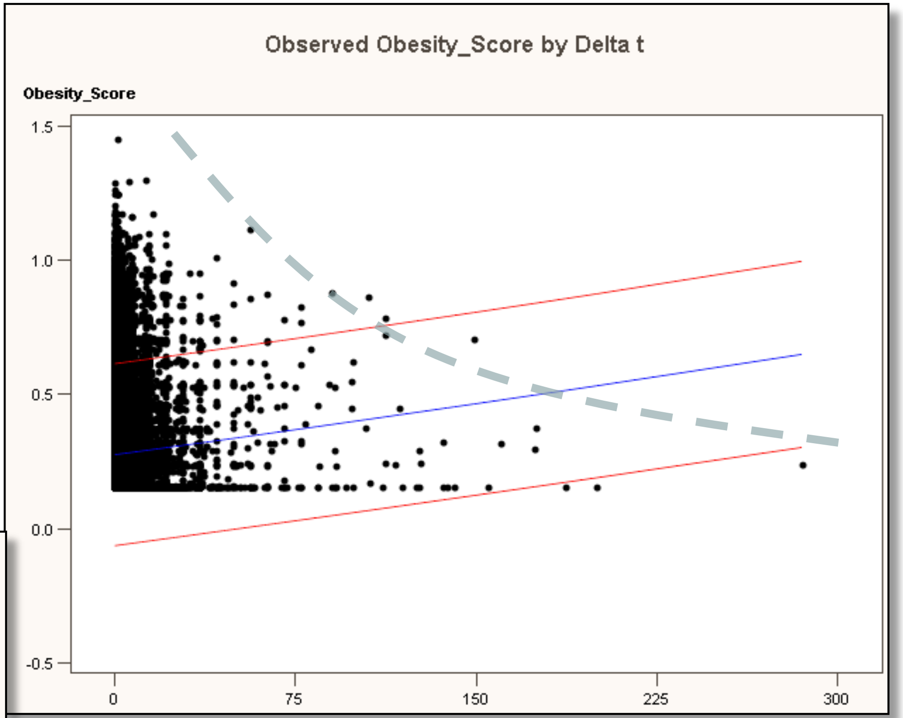
- **Individual scores did not vary with $\Delta$t as expected** (e.g. dashed line)
  - *Substantial variation in scores at all $\Delta$t , including $\Delta$t=0*
  - *Indicates unobserved processes of adherence variation*
  - *Missing values = 525, used 89753 cases*
- **Plot shows predicted 95% confidence limits**
  - *with n=89753, p<.0001*

| Estimation Summary | |
|---|---|
| Method | Gauss-Newton |
| Iterations | 7 |

| Source | DF | Sum of Squares | Mean Square | F Value | Approx Pr > F |
|---|---|---|---|---|---|
| Model | 1 | 3.3223 | 3.3223 | 111.15 | <.0001 |
| Error | 89751 | 2682.7 | 0.0299 | | |
| Corrected Total | 89752 | 2686.0 | | | |

| Parameter | Estimate | Approx Std Error | Approximate 95% Confidence Limits | |
|---|---|---|---|---|
| psi | -2.2089 | 0.000610 | -2.2101 | -2.2077 |
| rho | 2.4845 | . | . | . |
| gamma | -0.00049 | 0.000046 | -0.00058 | -0.00040 |

$$K(\Delta t) = \psi + \rho e^{-\gamma \Delta t}$$




$\Delta t$

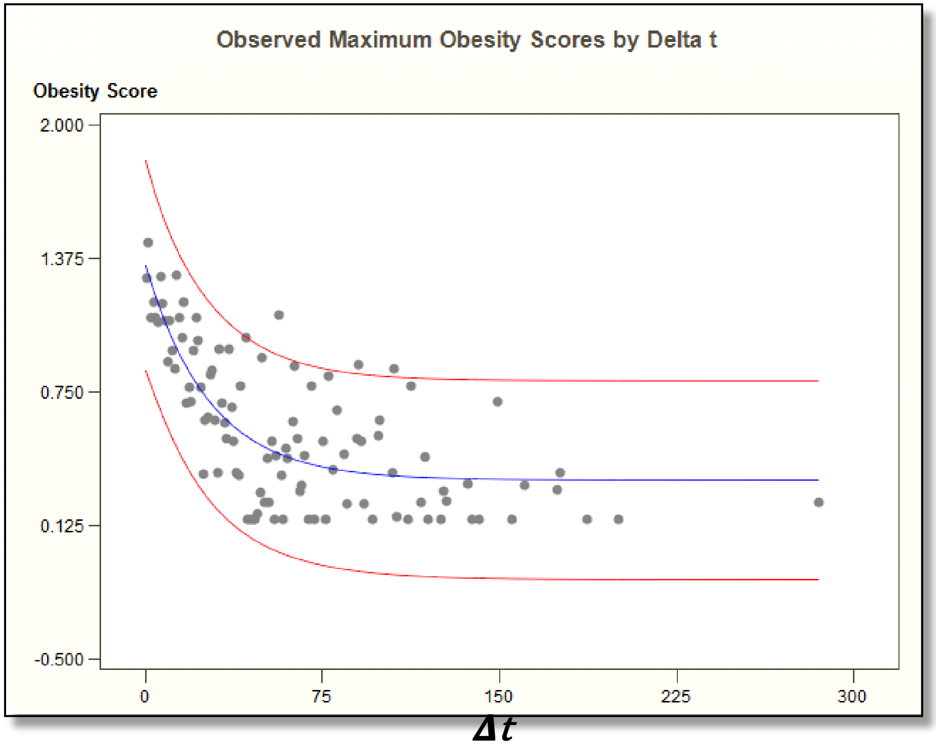
# Findings

## Observed Max Obesity Diagnosis Scores

- **Transformed data to apply max score at each $\Delta t$**
  - N = 105 –only max scores included
  - Applied equal weighting to each $\Delta t$
- **Regress K($\Delta t$) Max Obesity diagnosis scores on $\Delta t$**
  - Curve shows how $\Delta t$ lowers the score of everyone
  - Plot shows predicted 95% confidence limits of decay curve

| Parameter | Estimate | Approx Std Error | Approximate 95% Confidence Limits | |
|---|---|---|---|---|
| psi | 0.3375 | 0.0454 | 0.2475 | 0.4275 |
| rho | 1.0045 | 0.0889 | 0.8282 | 1.1807 |
| gamma | 0.0372 | 0.00717 | 0.0229 | 0.0514 |

$$K(\Delta t) = \psi + \rho e^{-\gamma \Delta t}$$




| Estimation Summary | |
|---|---|
| Method | Gauss-Newton |
| Iterations | 14 |

| Source | DF | Sum of Squares | Mean Square | F Value | Approx Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 7.5384 | 3.7692 | 71.09 | <.0001 |
| Error | 102 | 5.4084 | 0.0530 | | |
| Corrected Total | 104 | 12.9468 | | | |

# Findings

## Analysis of encounter deviations from max performance

### Evaluated 3 classes of factors that may influence individual performance

- **Work**
  - ***Time with patient:*** ***APPT_LENGTH (in minutes)***
- **Workplace**
  - ***Department Specialty***
    - **Dept_PCP – serves Primary Care Pediatrics**
    - **Dept_Weight – serves Pediatric Weight Control**
    - **Dept_Comorbid - serves obesity comorbid conditions**
      - ***Cardiology, nephrology, endocrinology, etc.***
  - ***Department workload***
    - **Dept_Vol – number of obesity cases in 2013**
    - **ObesityLoad – ratio of obesity cases to caregivers in department**
  - ***Department Size – number of providers***
    - **CareProviders**
  - ***Department located in hospital:*** ***Hosp_Setting***
- **Worker**
  - ***Physician Specialty: is primary care or not - PhyPC***

| Variable | Mean | Std Dev | Minimum | Maximum | N |
|---|---|---|---|---|---|
| Dept_PCP | 0.3019113 | 0.4590895 | 0 | 1.0000000 | 90255 |
| Dept_Weight | 0.0466789 | 0.2109513 | 0 | 1.0000000 | 90255 |
| Dept_Comorbid | 0.2010526 | 0.4007895 | 0 | 1.0000000 | 90255 |
| Dept_Vol | 1505.54 | 1284.95 | 1.0000000 | 5067.00 | 90255 |
| ObesityLoad | 217.2985873 | 145.2268863 | 1.0000000 | 598.0000000 | 90255 |
| CareProviders | 7.9678799 | 8.9905155 | 1.0000000 | 60.0000000 | 90255 |
| Hosp_Setting | 0.3502625 | 0.4770547 | 0 | 1.0000000 | 90278 |
| APPT_LENGTH | 24.8088682 | 17.4202364 | 5.0000000 | 480.0000000 | 90278 |
| PhyPC | 0.3017014 | 0.4589989 | 0 | 1.0000000 | 90278 |

# Findings

## Analysis of encounter deviations from max performance

- **Positive deviation = better performance**
- **Evaluated factors that influenced individual deviation from predicted max performance**
  - **N = *89730***
  - **P < *.0001***
  - **Adjusted R-square: *0.1762***
- **Department type (Dept_PCP) had largest positive effect : + *1.01***
- **Physician Specialty in Primary Care (PhyPC) had largest negative effect: *-0.76***

| | |
|---|---|
| Number of Observations Read | 90278 |
| Number of Observations Used | 89730 |
| Number of Observations with Missing Values | 548 |

| Analysis of Variance | | | | | |
|---|---|---|---|---|---|
| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
| Model | 9 | 661.12823 | 73.45869 | 2133.33 | <.0001 |
| Error | 89720 | 3089.40839 | 0.03443 | | |
| Corrected Total | 89729 | 3750.53662 | | | |

| | | | |
|---|---|---|---|
| Root MSE | 0.18556 | R-Square | 0.1763 |
| Dependent Mean | -1.00817 | Adj R-Sq | 0.1762 |
| Coeff Var | -18.40604 | | |

| Parameter Estimates | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Variable | Label | DF | Parameter Estimate | Standard Error | t Value | Pr > \|t\| | Standardized Estimate | 95% Confidence Limits | |
| Intercept | Intercept | 1 | -1.15963 | 0.00197 | -589.12 | <.0001 | 0 | -1.16349 | -1.15577 |
| Dept_PCP | Dept_PCP | 1 | 0.45073 | 0.05365 | 8.40 | <.0001 | 1.01203 | 0.34558 | 0.55588 |
| Dept_Weight | Dept_Weight | 1 | 0.13982 | 0.00328 | 42.65 | <.0001 | 0.14427 | 0.13339 | 0.14624 |
| Dept_Comorbid | Dept_Comorbid | 1 | 0.07041 | 0.00178 | 39.49 | <.0001 | 0.13800 | 0.06692 | 0.07391 |
| CareProviders | CareProviders | 1 | 0.00434 | 0.00009713 | 44.63 | <.0001 | 0.18904 | 0.00414 | 0.00453 |
| ObesityLoad | ObesityLoad | 1 | 0.00011538 | 0.00000813 | 14.19 | <.0001 | 0.08196 | 0.00009944 | 0.00013131 |
| Dept_Vol | Dept_Vol | 1 | -0.00002799 | 8.88334E-7 | -31.51 | <.0001 | -0.17606 | -0.00002973 | -0.00002625 |
| PhyPC | | 1 | -0.33683 | 0.05369 | -6.27 | <.0001 | -0.75618 | -0.44205 | -0.23160 |
| APPT_LENGTH | APPT_LENGTH | 1 | 0.00244 | 0.00004076 | 59.96 | <.0001 | 0.20810 | 0.00236 | 0.00252 |
| Hosp_Setting | | 1 | 0.05284 | 0.00146 | 36.23 | <.0001 | 0.12325 | 0.04998 | 0.05570 |

# *Applications*

# Application

## *Modeling for Performance Optimization*

- **Gap Analysis**
  - ***Cognitive/Social/Behavioral Model Analysis identifies critical elements***
  - ***Assessment tools determine readiness state***
- **Personnel Selection & Learning System Design**
  - ***Assessment tools for applicant screening & planned learning rate***
  - ***Optimize media & pedagogy for minimum time to readiness***
- **Used to Develop / Deploy Performance Support / Memory Aids**
  - ***Cognitive - Memory***
  - ***Decision Support***
  - ***Communication aids***
- **Performance Retention Models for practice schedule design**
  - ***optimum practice frequency***
  - ***identifies what to practice & when***
  - ***assessment & reinforcement schedule for optimum sustainment***
- **Models assist resource assignment to optimize performance**
  - ***Selection of "ready" resources for critical performance***
  - ***Guides resource rotation to maintain readiness***

***Performance Modeling Enables Readiness***

# Modeling for Performance Optimization

***Extending to system performance prediction models***

- **Performance models are scalable**
  - ***from individual to teams for team readiness assessment***
  - ***from teams to organizations for total readiness assessment***
- **Models enable distribution of resources for optimized return on investment**
- **Models enable distribution of reinforcement schedules at organizational level**
- **Models provide metrics for managing organizational objectives**
  - ***Identify possible and expected performance levels***
  - ***Assessments identify performance shortfalls where application of performance improvement actions needed***
- **Models provide for rational, agile management**
  - ***Enables replacement of "we've always done it this way" with demonstrably effective alternatives***
  - ***Enable maximization of affordability goals***

***Performance Modeling Enables Affordable Total Force Readiness***

# Skill Retention Issues in Education

## *Classroom to school system*

- **Procedural performance can be varied resulting in skill retention issues**
  - ***Teachers doing administrative service***
  - ***Specialists teaching general courses***
- **State of the Art and Practice is in continuous change**
  - ***New media and instructional techniques***
  - ***New technologies and learning content***
- **Data may exist & be obtainable to properly parameterize models**
- **Certification & skill maintenance is ongoing & recognized issue within the industry**
- **Educational performance assessment is a strong political issue in local settings**

***Performance modeling leads the way to enhancing the education system***

# Healthcare
## *Physicians, technicians & nursing*

- **Procedure performance can be varied resulting in skill retention issues**
  - ***Specialists doing generalist work***
  - ***Generalists doing specialist work***
  - ***Randomness & frequency of illnesses & injuries define experience base***
- **EHR data often exists to parameterize models**
- **Certification & skill maintenance is ongoing recognized issue within industry**
- **Healthcare Industry seeks models for quality assurance**
  - ***Providers and practitioners***
  - ***Insurance providers***
- **Serving Military physicians and reservists have recognized risk of skill decay**

***Performance modeling leads to quality, safe, affordable healthcare***

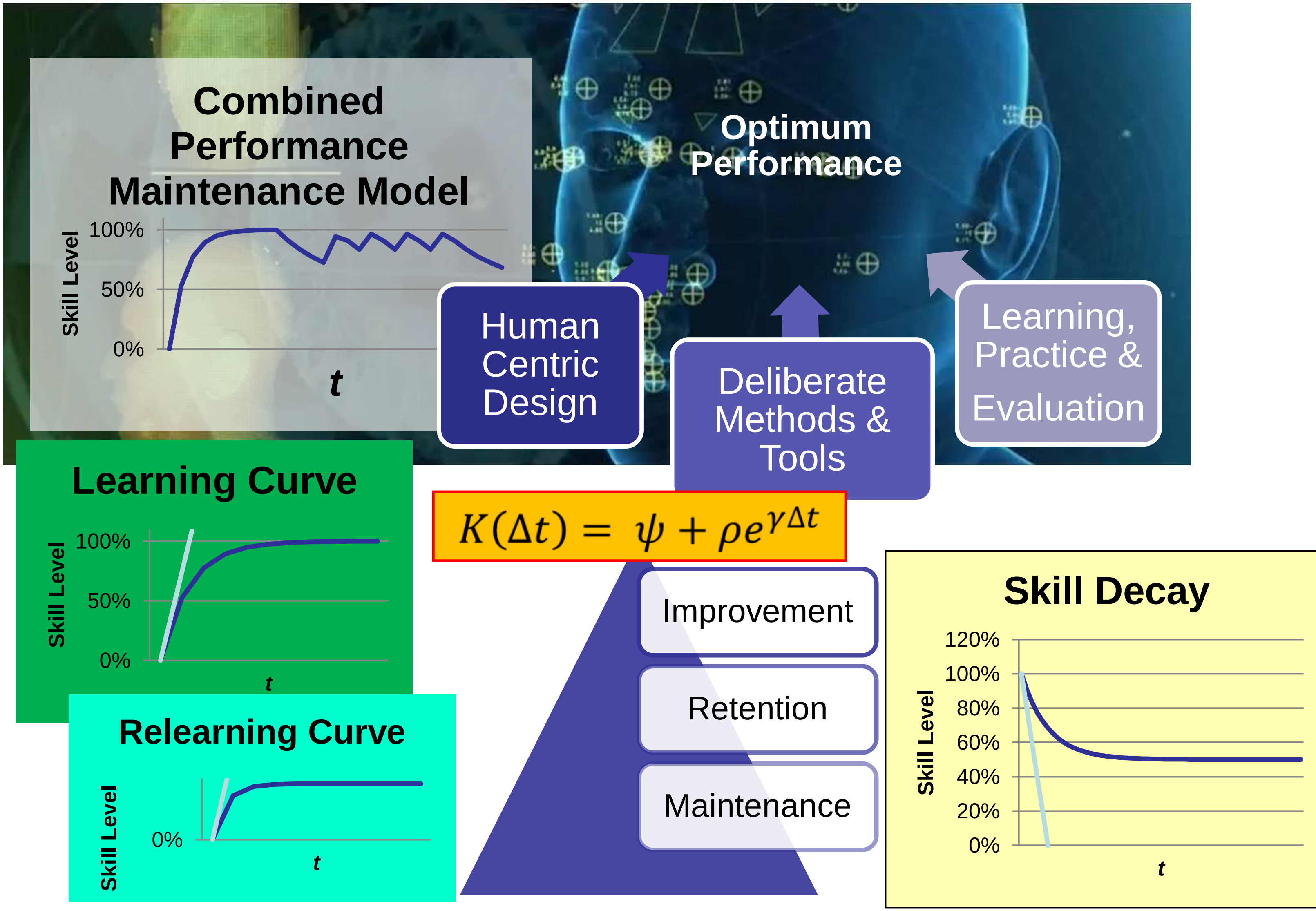
# Department of Defense

*Performance modeling across the Services*

- **Procedural performance & deployments can be varied resulting in skill retention issues**
  - ***Cultural Engagement is complex & varies from location to location***
  - ***Combat skills intermingled with leadership & cultural needs***
  - ***Need for diverse skills due to force reductions***
- **State of the Art and Practice is in continuous change**
  - ***New technologies & agile tactics***
  - ***Agile enemy requires agile response***
- **Much data may already exist to properly parameterize models**
- **Certification & skill maintenance is ongoing & recognized issue within Services**
- **Performance assessment, AAR technologies & performance modeling are recognized requirements**

***Evidence-based performance modeling meets a growing DOD need***

# Our customer wants optimum performance




***Performance forecast modeling is a key affordable discriminator***

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